SBE16 HAMBURG

STRATEGIES
STAKEHOLDERS
SUCCESS FACTORS

ZEBAU

Conference Proceedings

Sustainable Built Environment Conference 2016 in Hamburg

Strategies, Stakeholders, Success factors

7th - 11th March 2016

KIT Karlsruhe Institute of Technology

HOCHSCHULE FÜR ANGEWANDTE WISSENSCHAFTEN MÜNCHEN

HCU HafenCity Universität Hamburg

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Program Overview

Time	Monday 7.3.2016	Tuesday 8.3.2016	Wednesday 9.3.2016	Thursday 10.3.2016	Friday 11.3.2016
8.00-9.00 a.m.		Registration	Registration	Registration	
9.00-10.30 a.m.		Opening Keynotes	Scientific sessions / Housing Industry Day	Scientific sessions / Day of Architecture, Planning & Engineering	PhD Session / Excursions
10.30-11.00 a.m.		Coffee	Coffee	Coffee	Excursions
11.00 a.m.-12.30 p.m.		Scientific sessions / Day of Municipalities	Keynote Session UN Climate Change Conference	Scientific sessions / Day of Architecture, Planning & Engineering	PhD Session / Excursions
12.30-2.00 p.m.		Lunch	Lunch	Final Session / Lunch	
2.00-3.30 p.m.	Excursions / Pre-Registration	Scientific and special sessions / Day of Municipalities	Scientific and special sessions / Housing Industry Day	Final Session, Excursions / Day of Architecture, Planning & Engineering	PhD Session
3.30-4.00 p.m.	Excursions / Pre-Registration	Coffee	Coffee	Excursions / Coffee	
4.00-5.30 p.m.	Excursions / Pre-Registration	Scientific and special sessions / Day of Municipalities	Scientific and special sessions / Housing Industry Day	Excursions / Day of Architecture, Planning & Engineering	
5.30-7.00 p.m.	Warm-up and exhibition opening	Welcome and Networking-Reception for all participants (Handelskammer)	Get Together and Award Ceremony (Holcim Study Award)		

Scientific Session

Session in German language

PhD Session

SBE16 Hamburg

International Conference on Sustainable Built Environment Strategies – Stakeholders – Success factors

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Organised by

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KIT Karlsruhe Institute of Technology

Hochschule für angewandte Wissenschaften München

HCU HafenCity Universität Hamburg

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SBE16 Hamburg – a brief introduction

„SBE16 Hamburg“ is an international scientific conference on sustainable building that is part of the Sustainable Built Environment Conferences series 2016/2017. The series is run by the International Council for Research and Innovation in Building and Construction (CIB), the International Initiative for a Sustainable Built Environment (iiSBE), the Sustainable Building and Climate Initiative (SBCI) of the United Nations Environment Programme (UNEP), and the International Federation of Consulting Engineers (FIDIC).

The conference series follows a ten-year tradition. Held in three-year intervals in different cities around the world, the conference series has established itself as one of the major events in this field. Following the World Conference in Barcelona in 2014, 20 regional conferences will take place in 2016 to prepare for the next World Conference in Hong Kong in 2017 and bring together thousands of players in the field of sustainable construction.

The title of SBE16 Hamburg, the regional conference in Germany, is „**Strategies, Stakeholders, Success factors – Strategien, Akteure, Erfolgsfaktoren**.“ With this title SBE16 Hamburg exemplifies what the general framework for sustainable construction must consist of and which procedures, influences, interactions and stakeholders, in fact, need to be part of a successful implementation. It focuses geographically on Germany, Scandinavia, Poland, the Baltic States and Russia, and is aimed at scientists, architects, city planners and engineers, politicians, stakeholders, the real estate industry, and municipalities.

The **Scientific Advisory Board** of SBE16 Hamburg is composed of more than 80 international and recognized scientists and experts who evaluate independently and anonymously all submissions to the conference and thus ensure the scientific quality of the event. Presiding over the Scientific Advisory Board are Professor Thomas Lützkendorf (Karlsruhe Institute of Technology), Professor Peter O. Brown (HafenCity University Hamburg), and Professor Natalie Eßig (University of Applied Sciences Munich).

The **multi-faceted program** provides congress participants with the opportunity for intensive exchanges and knowledge gain and thereby also fosters experiences. The aim is to bring together scientists, planners and representatives from politics and business to discuss science, policy and practice with one another, thus contributing to a targeted and effective exchange of knowledge.

SBE16 Hamburg consists of various components: a combination of scientific knowledge, research results, and examples of practical implementation and innovation. The conference planners have made this possible by building into the agenda a diverse lecture program, ample opportunities for communication and networking, and a varied menu of excursions.

The lecture program consists of plenary, scientific contributions, and, for German-speaking participants, **subject-specific theme days**.

In the **plenary** opening by the event organizers, speeches and greetings will be given by representatives of the main sponsors of SBE16 Hamburg as well as German and international representatives of the political and scientific arenas. The national political representatives include Federal Minister for the Environment, Nature Conservation and Nuclear Safety, Dr. Barbara Hendricks and the Second Mayor of the Free and Hanseatic City of Hamburg, Katharina Fegebank. Nils Larsson (iiSBE) and Prof. Dr. Lützkendorf (KIT) will cover the significance of this conference series. Keynotes will be delivereyd by Professor Mojib Latif of GEOMAR Kiel and Hans-Dieter

Hegner from the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety.

A program of outstanding speakers will accentuate once again the results of the **UN Climate Change Conference in Paris COP 21** and highlight key issues and challenges during the second plenary session on Wednesday morning. Nils Larsson (iiSBE) will convey his impressions of his participation at the Paris conference. He will be followed by Stefan Schurig (World Future Council) on the impact on future cities and Dr. Harry Lehmann (German Federal Environment Agency) on the consequences of the UN climate summit for the construction and property industry.

The **scientific sessions** will take place over the three main days of the event (Tuesday to Thursday) with parallel sessions consisting of 10-minute presentations by national and international researchers, whose submissions were reviewed and selected by the SBE15 Hamburg Scientific Advisory Board. Around 150 papers from 34 countries will be presented, and each presentation will be followed by a brief discussion. In addition, contributions in the form of posters will be introduced in short talks at the end of some sessions.

The opportunity to **network and talk** with others is an essential part of SBE16 Hamburg. An accompanying exhibition of industrial partners, ‘chat breaks,’ and various evening events and excursions offer participants the chance to discuss scientific findings and link them with practice.

The **exhibition** takes place in the foyer of the HafenCity University, which forms the spatial intersection of all other activities of SBE16 Hamburg. Designed as a communication area, the space allows visitors to learn about the innovations of the supporting partners.

Within the program framework, on Monday, Wednesday and Friday the interplay of lectures and discussions will be rounded by several **excursions**. Through these conferences participants will be able to witness examples of sustainable building in practice. The program includes excursions to a variety of interesting locations and construction projects, such as the urban development project HafenCity Hamburg, where the event venue - HafenCity University (HCU) - is located.

SBE16 Hamburg thematic focuses:

- Strategies and frameworks for sustainable construction and sustainable urban development
- Innovative concepts and case studies in sustainable neighborhood and urban development
- Project development and sustainability
- Application of sustainability tools and methods in the construction and property industry
- Research on innovative materials and products
- Expression of sustainability in education and training

The program committee of the SBE16 Hamburg welcomes you!

  

Prof. Dr.-Ing. habil. Thomas Lützkendorf,
Karlsruhe Institute of Technology (KIT), Head of the Scientific Committee

Prof. Dr. Natalie Eßig, Munich University of Applied Sciences (MUAS)
Prof. Peter 0. Braun, HafenCity University Hamburg (HCU)

Both the planning, construction and operation of buildings in accordance with the principles of sustainable development, and the further development of the building stock and infrastructures to improve the quality of the built environment require the active involvement of all relevant stakeholders. Being dedicated to these topics, SBE16 Hamburg has a scientific program that is specifically addressed, among others, to representatives from research and education and to the staff of municipal administration, housing companies, and real estate and portfolio management companies. The discussions of how aspects of sustainability can be integrated in the processes of planning and decision making, of which strategies and solutions are available, and of how success can be measured are the thematic continuation of the SB 13 Munich Conference. It is not only the provision of calculation and evaluation methods, of design principles and design tools or of new structural and technical solutions that decides on the success of sustainable construction. As a matter of fact, the respective approaches need to be in demand, to be applied successfully, and to offer clear advantages to the environment, society, and industry. SBE16 Hamburg tries to overcome the traditional separation between science and practice. Contributions on the further development of methodical approaches are complemented by presentations of practical examples and analyses of experiences.

The international sustainable building conference series, within which Hamburg is the host city, has developed its range of subjects and has clearly expanded its focus to comprise all aspects of the design of a sustainable built environment. SBE16 Hamburg caters to this development by offering a program emphasizing a sustainable development in neighborhoods and urban districts. This focus is supported by discussions of issues related to the interaction between buildings and the grid. In addition, SBE16 Hamburg deals with the further development of national and company-owned building stock to achieve the objectives of climate protection and with the sustainable planning, construction and operation of civil engineering structures and constructed assets.

We are pleased that we will be able to benefit from many contributions by young researchers and PhD students. Whereas it becomes clear that the issue of sustainability is rather widespread in research and practice, future generations of specialist and executive staff may profit from some sessions dedicated to the integration of aspects of sustainability into the further education of planners, real estate agents, and specialists for property evaluation.

The conference is the perfect platform for scientific exchange between national and international participants. The results of inter- and transdisciplinary research projects with partners from several countries are presented in various contributions, and international experience is communicated.

We are very grateful to the members of the International Scientific Committee who have ensured the scientific quality of the conference by participating in the preparation and holding of SBE16 through reviewing papers and taking over organizational tasks.

We wish all guests and participants successful days and interesting encounters while being in Hamburg.

Thomas Lützkendorf, Natalie Eßig, Peter Braun

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GPEE – German Polish Energy Efficiency Project
www.gpee.net
funded by Germany Federal Ministry of Education and Research and Ministry of Science and Higher Education, Republic of Poland

HEE – Horst Erichsen Energy
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iiSBE – International Initiative for a Sustainable Built Environment
www.iisbe.org

PLEEC – Planning for Energy Efficient Cities
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SBE16 HAMBURG
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All information on the SBE16 Hamburg Conference can be found on **www.sbe16hamburg.org**

The full paper proceedings with ISBN and DOI can be downloaded on http://digbib.ubka.uni-karlsruhe.de/volltexte/1000051699

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SBE16 Hamburg

Program overview

Tuesday, 8th March 2016

Location:	HOLCIM Forum	Lecture room 150	Room 2.102	Room 2.104	Room 2.105	Room 2.015	Lecture room 200	Room 2.103
8.00-9.00 a.m.	Registration							
9.00-10.30 a.m.	**Opening Keynotes** (HOLCIM Forum)							
	Coffee							
11.00 a.m.-12.30 p.m.		**Ses 1.2:** Energy supply for urban areas		**Ses 1.1:** International experience		**Ses 1.3:** Valuation and selection of construction products	**2A:** BMUB – Nachhaltige Kommunen	10.45 Uhr **2B:** Lösungen der Energie-versorgung Ansätze für Kommunen
	Lunch							
2.00-3.30 p.m.	**Sp 01:** PLEEC – Planning for Energy Efficient Cities I	**Ses 2.1:** Net zero and plus energy buildings	**Ses 2.2:** Education I	13.45 Uhr **3G:** Sportstätten - Förderer des nachhaltigen Bauens?		**Sp 03:** Open international data network for LCA at building level I	13.45 Uhr **3A:** Projekte der Klimafolgen-anpassung	13.45 Uhr **3B:** Mittel und Wege zum Erreichen kommunaler Klimaschutz-ziele
	Coffee							
4.00-5.30 p.m.	**Sp 02:** PLEEC – Planning for Energy Efficient Cities II	**Ses 3.1:** Building integrated solutions and new technologies	**Ses 3.2:** Education II	**Ses 3.3:** Infrastruc-tures and constructed assets		**Sp 04:** Open international data network for LCA at building level II	**4A:** Regenwasser-management	**4B:** Aktuelle Herausforde-rungen – Potenziale und Lösungs-wege
7.00 p.m.	**Welcoming and Networking Reception (Chamber of Commerce, Handelskammer)**							

Wednesday, 9th March 2016

Location:	HOLCIM Forum	Lecture room 150	Room 2.102	Room 2.104	Room 2.105	Room 2.015	Lecture room 200	Room 2.103
8.00-9.00 a.m.				Registration				
9.00-10.30 a.m.		**Ses 4.1:** Urban design and mobility	**Ses 4.2:** Timber structures and biobased products	**Ses 4.3:** Standardisation, regulation, innovation		9.30 Uhr **1D:** Hamburger Stadtentwicklung	**1C:** GdW – Nachhaltigkeitskodex der Wohnungswirtschaft	
				Coffee				
11.00 a.m.-12.30 p.m.	**5.1 Keynote Session:** COP21 Paris and the consequences						10.45 Uhr **2C:** Nachgefragt – die drei Säulen nachhaltiger Wohnungswirtschaft	
				Lunch				
2.00-3.30 p.m.		**Ses 6.1:** Development of urban districts I	**Ses 6.2:** Sustainable assessment systems – further development and application	**Ses 6.3:** Portfoliomanagement & improvement of building stock	**Ses 6.4:** Stakeholder perspectives and actions I	**Sp 05:** Energy efficient facades – technologies and measurement I	13.45 Uhr **3C:** Wohnraum für Flüchtlinge I	13.45 Uhr **3D:** Zukunftsorientiert und nachhaltig: Energie für heute und morgen
				Coffee				
4.00-5.30 p.m.		**Ses 7.1:** Development of urban districts II	**Ses 7.2:** LCA-application and further development	**Ses 7.3:** Public sector – activities and experiences	**Ses 7.4:** Stakeholder perspectives and actions II	**Sp 06:** Energy efficient facades – technologies and measurement II	**4C:** Wohnraum für Flüchtlinge II	**4D:** Nachhaltige Quartiersentwicklung
6.00 p.m.	**Holcim Study Prize „Sustainability" – Best Bachelor and Master Thesis at HCU**							
8.00 p.m.	**Late Night Event: Nighttime Harbor Cruise**							

Thursday, 10th March 2016

Location:	HOLCIM Forum	Lecture room 150	Room 2.102	Room 2.104	Room 2.105	Room 2.015	Lecture room 200	Room 2.103
8.00-9.00 a.m.	Registration							
9.00-10.30 a.m.		**Ses 8.1:** Urban development under specific conditions	**Ses 8.2:** Construction products and processes	**Ses 8.3:** Design stages – importance and contribution		**Ses 8.4:** Cooling, ventilation and air conditioning	9.30 Uhr **1F:** Nichtwohn-gebäude – Finanzierung und Qualitäts-sicherung	**1E:** dena – Turbo für die energetische Sanierung
Coffee								
11.00 a.m.-12.30 p.m.		**Ses 9.1:** Urban planning and energy	**Ses 9.2:** Cost and value – the economic point of view	**Ses 9.3:** Collaboration and user involvement		**Ses 9.4:** Resource efficiency and recycling	10.45 Uhr **2F:** Nichtwohnge-bäude – Energie-effizienz in der Praxis	10.45 Uhr **2E:** DBU – Klimafolgen-anpassung und Regen-wasser-management
Lunch / Packed Lunches								
	1.00-2.00 p.m. **Closing Ceremony**						13.45-15.15 Uhr **3F:** Nachhaltig und effizient – Bau-en und Heizen mit Holz	13.45-15.15 Uhr **3E:** DBU – Klimafolgenan-passung und Regenwasser-management
After Closing Ceremony	**Excursions**							
7.00 p.m.	**Late Night Event**							

SBE16 Hamburg

Full paper

in alphabetical order

30 years after – case study of ´Ökologische Gemeinschaftswohnanlage Nofels´ (ecological housing cooperative Nofels)

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Summary

The study investigates an autonomous housing project for eleven families in Feldkirch/Austria[1]. This project combines a radical mix of societal alternative, typological innovation and tectonic efforts.
The project addressed four key design objectives: ´radically cost efficiency´, ´ecological approach´, ´individual homes in a communal frame´ and the possibility of developing an adaptive ´self-build´ system. All four objectives required a strong tectonic strategy.

´Ecological buildings´ of the 80´s had a stronger focus on ´natural´ materials and healthy indoor climate than on energy consumption. Innovative structural connections, thin slabs of massive wood, ´Trombé walls´, were implemented with sophisticated details. Another unique aspect was the incorporation of individual and bivalent hypocaust heating systems into each unit.

The roles of the architect of this dwelling included and combined those of designer, mediator, mastermind for overcoming legal obstacles, accountant, supervisor and building instructor.

The aim of this paper is to compare how the original design, the group processes and the execution of the housing estate performed over three decades and it draws conclusions for self build projects in the present, which seem to have a renaissance in different countries.

Keywords: communal housing, ecological building, low-cost, adaptive, self-building

1. Introduction

In winter 1985, five young families in Feldkirch/Austria started the idea of building a joint housing project that fulfils their wishes:

- living individually in a communal frame
- living self-determined in respect to the formation of their home
- living ´ecological´,
- building as economic as possible

The author of this paper was selected as the architect, having had experience in participatory design projects before.
After placing an ad in a local newspaper, 22 families came to a first meeting. They all had in common a lot of dreams, many ideas for a more ecological life-style but no building site or relevant money and savings.

For a design strategy it became clear from start that only a very flexible, resilient and adaptive tectonic concept could merge the individual and individualistic desires (in size of as well as in standard of the home) with the needed radical low-cost approach and the ´ecological program´.

During the preparatory discussions, the concept of ´growing and shrinking house´ was presented to the group. Three different sizes of start-up homes with 95m2, 110m2 and 130m2 were proposed – all of them with the capacity to be extended and all of them also separable into two smaller apartments. The smallest standard house should not cost more than 600.000 ATS (total price including land). More informative: in 1985, this was about 50% of the regional market price for a conventional home with the same size.

It took eight months until a scouting group spotted a site in the boundaries of Feldkirch. The site had 3225 m2 and it was inexpensive due to its geometry: the length of 150 meter and the width of only 21.5 meter did not make it interesting for investors or building companies. A car access to the center was economically impossible. This was an advantage for our group, where car-free access was on the ecological agenda anyway (Fig 1).

Fig. 1 The long site is situated close to a beautiful forest in an area, were only space consuming one-family homes existed. There are carports at the eastern and the western end of the site with no car access to the units. The project is structured in 6+3+2 units, connected by a 105 meters long corridor in the north. The gaps are partly filled with a community house and an office.

In the following collective design and decision processes, the number of families reduced to eleven. Some did not like the area, others got scared in the last moment of the needed efforts of such a communal undertaking and its financial risks. The ones who decided to build together signed a collective purchase contract and ´started the adventure´[2].

2. Methodology

This paper is a case study about this very political project and a reflection with special focus on its tectonic aspects. It documents the project´s history, based on parameters decided by the group, architectural drawings, the building process, comparative photos and interviews of six inhabitants. It illustrates problems and contradictions during the process of design, building and habitation. It presents and discusses the changes that happened over time and thereby it focuses on the tectonic aspects which supported these changes.

The project was explicitly designed for change and adaptation. How did this change happen and how fit was the concept? How many of the visions were followed over time and how did the building respond to the changes?

After the experience of almost 30 years, the comparison between the initial ideas and design with the status of 2015 on different layers seems to be very fruitful for ongoing discourses on adaptability, life cycle design and self-determined housing forms, which are recently developing in many places[3]. Considering this frame, ´Ökologische Gemeinschaftswohnanlage Nofels´ is a critical case having strategic importance in relation to the discourse on habitation.

3. Results

3.1 original design parameters

After discussions of almost a year, the general group agendas of ´communal + self-determined + ecological + low-cost´ turned into 39 design parameters, such as common spaces for group activities and children, no fences between gardens, self-administration, unsealed surfaces, natural building materials or cost optimization by self-building. They had to be set into context of the specific site and they became binding guidelines based on protocolled group decisions.
Originally, the whole project was designed with (cheaper) flat roofs and a roof garden to compensate the generally small private gardens. As there was no chance to get building permission for this proposal, the 45 degree gabled roof was offered as a compromise to what was called by building authorities ´customary in place´ (Fig 2). The owners later considered this forced change as an advantage despite original higher costs: In seven units over time, the attics turned into additional habitable space.

Fig. 2 left: view from East with private gardens and units individually coloured to the south right: view from North-East showing the communal access with the connecting corridor which was designed as a multifunctional space with 261 cm inner width. (Pictures taken 1989)

3.2 the structure and the logistics or the tectonics of ´Fügen und Fugen´

´Fügen´ is an old German word and means ´join together´ or ´fit into each other´. The meaning is not limited to a technical connection but includes a strong metaphoric and figurative content. The notion of ´fügen´ is not only used for describing a process where timber meets timber or timber meets brick. It implies in a wider tectonic sense how design decisions and technical solutions relate to the objectives of ´ecological´, ´low-cost´, adaptive´ and especially to ´self-building´. In that sense, ´fügen´ has a wide aspiration.

One example in the Nofels housing project is the stairs – a mix of industrially prefabricated parts designed for self-assembling. The prefabricated steps are cheaply produced of only 3mm bent tin, hanging from the beams that support the wooden slab. They are easy to assemble by amateurs with ten screws each step and the round steel bars form at the same time the railing of the gallery. The shape and the thin materialization optimize the useful space underneath the stairs. Loose and small coconut fibre carpets reduce noise and make the stair non-slip. According to newer building regulations, the wide distances between the vertical bars would be illegal (Fig.3).

Fig.3 hanging stair of inexpensive and adjustable steel elements, screwed in glulam beams

The eleven homes were designed in a rigorous ´tartan grid´ of 261 cm + 12 cm for primary structure. The measure system generates a total footprint of each individual unit of 8,07 x 8,07 m or 65 m2/floor when fully built. The ´mirroring´ size of ground floors and the 64 m2 gardens has been considered by the group as a good balance between space quality and economy.

The grid with a maximum span of 261cm allows a very cost effective slab in not-laminated massive wooden floor boards d=6,5 cm, double-tongued and grooved, not polished. These thin (and easy to cut) slabs reduce the total building volume (and therefore costs) by minimizing building height. It is an easy system for self-building the interior of the units after professional companies had built the masonry and the structural skeleton. (Fig. 4)

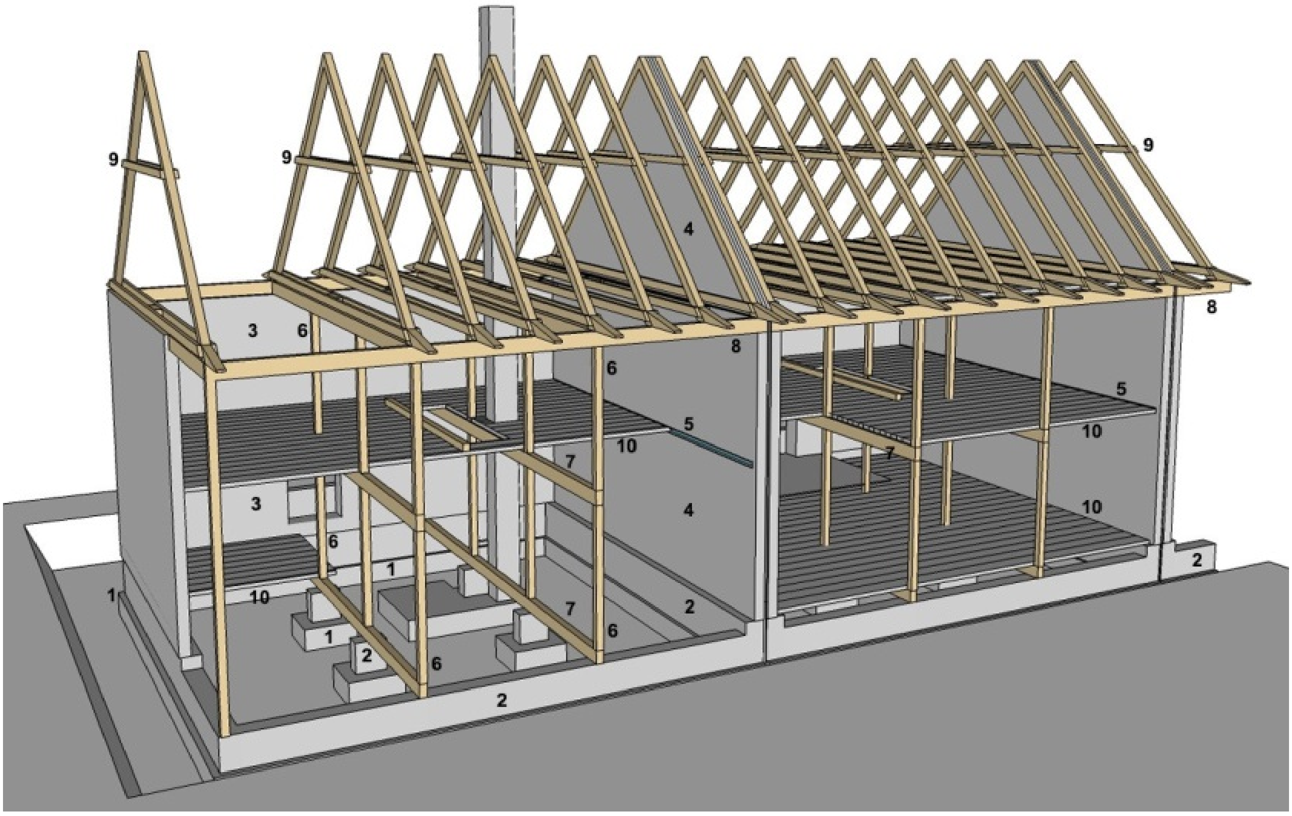

Fig. 4 1 foundation 2 concrete bricks 3 thermal brick 38 cm 4 acoustic brick 2x18 cm with insulation in between 5 u-steel profile with fish plates for slab 6 glulam posts 12/12
7 glulam beams 12/24 8 glulam beam 12/24 9 rafter frames 10/18 + 2 x boards 5/12 10 thin slab of massive wooden boards d= 6,5 cm, double-tongued and grooved, not polished

Traditionally, brick construction was and is the cheapest form of construction in Austria. So for cost reasons, as much brick as possible was used for enclosure (mainly walls to the north and sound insulated brick walls between the homes) and as little brick as possible for optimizing flexibility and changeability. This unorthodox ´hybridisation´ between massive walls in brick, a wooden skeleton structure with massive wooden slabs and a low-tech ´curtain wall´ to the south - although having strong advantages in indoor comfort, flexibility and cost reduction - created significant challenges on the level of detail, especially because of the very different tolerances in measurements between brick, timber and facade elements. The primary grid was rigidly applied without structural exceptions, also when colomns were positioned in the outdoor space. This further means there are freestanding columns in the living rooms (Fig 5), a reason for long discussions during the design process but no complaint after finishing the buildings.

Fig.5 left: hand-drawn plan of upper floor of the smallest unit with loggia, outdoor colomn and balcony. Red = brick, brown = wood. Centre: loggia of the same house Right: living room with freestanding colomn in the space and unpolished slab. (pictures taken 2015)

Following the concept of ´growing houses´, even the 261 cm wide northern corridor called ´Nordgang´ was constructed for possible extensions. The owners of house eleven built a Sauna and a resting room after ten years (Fig. 6). Instead of the original fence, a new wooden wall (with prolonged roof) obstructs the view to his private garden.

Fig. 6 Northern corridor 1988 and 2000 with vertical extension and transformed fence to wall

3.3 changing economy – changing values

After the houses were inhabited and over time, most inhabitants got better jobs[4] with higher incomes. Their actual costs for paying back the loans were as low as the rent for a medium sized apartment - the project was an economic success.

This rise of incomes was not without behavioral consequences: Besides making the smaller house bigger along the predesigned options and doing individual upgrading of interiors, a minority started to pressure the group for ´upgrading´ the common spaces contrary to the original group decisions. One example is the pavement and asphalt of the common access (Fig. 7). The ecological paradigm of ´unsealed surfaces for free water infiltration´ was given up in favor of ´tidiness´.

Fig. 7 left: access 1988, unsealed, rough and djungle-like Center and left: access ´ tidied´ by a pavement and ´sterile´ asfalt with ´domestisized´ pot plants (picture taken 2004)

Another fiercely disputed change was the transformation of the common ´northern corridor´. By group contract, this ´Nordgang´ had to be an open-plan connecting space. It performed as a meeting space, a dry storage for fire-wood, a space for plants, bicycles and buggies and it especially was a fantastic all-year playground for children[5] with their tricycle races, pedal car trips, table tennis competitions or simple quarrels. The main argument for closing the corridor came from three families with already older children, who felt disturbed by noisy children and who claimed the need of more private ´manipulation space´ outside their house. Finally after some years, in the eastern part the corridor was divided into individualized buffer rooms. In the western part, the corridor is still open due to a collective attitude of the people living there. (Fig 8).

Fig. 8 left and centre: still open part between house seven and eleven right: closed corridor
Group agreements only make sense if their is also a clear strategy for executing them against breaking minorities. A possible legal battle on the ground of the group contract was considered less productive for neighbourhood than the acceptance of the breaking of this contract (pictures taken 2014)

3.4 the building materials and details

Apart from tectonic potentials and low-cost aspecte, all materials were considered to be ´healthy´ and providing a positive indoor climate. The U-value of 0,4 of the homogenous brick (´thermo-brick´ with air-filled cavities and myriads of pores, generated by saw dust during the burning process - no attached thermal insulation) is very high in relation to standards and regulations of today. But the project is compact and 50 % of brick wall is in contact to the thermal buffer of the ´Nordgang´, which was always warmer than the outside temperature minima in winter. Additional, the thermal storage capacity and the humidity balance of the brick is an asset for the comfortable indoor climate.

All facade elements were detailed with a special joint and a compressed rubber sealing so they easily could be demounted and/or be reused in a changed configuration of the (growing) house.
This assembly detail proved to be very successful and still simple. Five families changed their windows to windows in passive house standard (U-value glass+frame < 0,8) over the last four years. Due to the original assembly detail, the windows could be changed in only one working day and no other craftsmen were needed for finish. This was communicated as strong appreciation by the owners and the craftsmen. (Fig. 9)

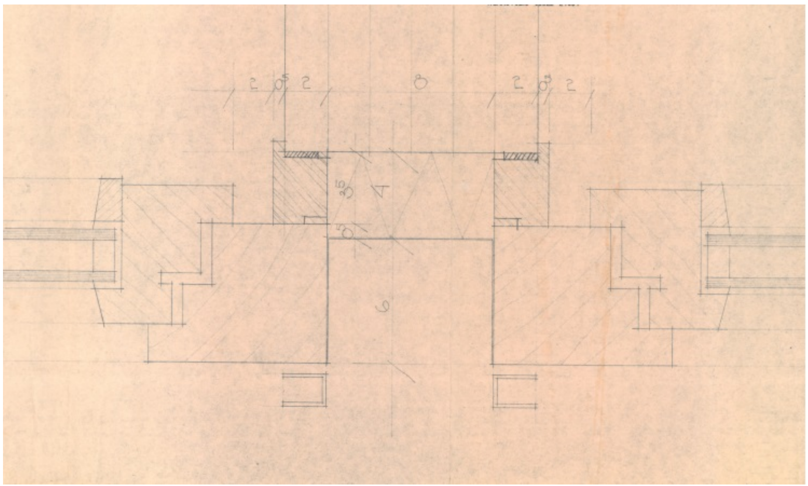

Fig. 9 left: original detail of window connection to glulam colomn, with exterior profiles for electric driven wooden shutters right: a new passive house window in wood with aluminum to the outside. The outside floor in larch exists since the house was built. (picture taken 2015)

3.5 the heating system – part of the tectonic strategy

In the alpine climate of Vorarlberg, a reliable heating system is essential.
The most common heating system in Austria around 1985 for new buildings was a boiler fuelled by natural gas with hot water circulation and radiators. For the group, three reasons made this heating system not an option from start:

- the dependency from natural gas and the predicted price increase of non-renewable fuels as well as their environmental impact
- a radiation heating with ´warm objects´ and radiating walls was considered as the most healthy and comfortable form of heating
- beside the idea of a resilient heating system (that also allowed heating and cooking in a state of energy emergencies), the memory on warm stoves in old farmhouses was a driving force for the design

Individual hypocaust heating was the selected solution. The central stoves as warm cores in each house with a big ´activity sofa´ was a modern reinterpretation of ´farmhouse romanticism´ (Fig. 10). This system was independent of fossil energy supply and gas prices and it allowed basic cooking, using legally collected firewood from the nearby forest. Furthermore, all rooms in all floors could be heated (in contrast to historic farmhouses). The system is truly self sufficient: No electricity, essential for pumps in water driven systems and for gas burners is required as the system works based on stack-effect of warm air only. In addition, eight of the eleven houses got a gas burner which was integrated in the same distribution system[6]. This provided the comfort of an automatic system independent of handling fire wood on a daily basis.

Fig 10 left and center: elliptic hypocaust stove with ´activity bed´ in living room right: translucent hypocaust wall in bathroom, made in profile glass, water resistent and used as towel dryer

These eleven heating systems were the continuation of a ´controlled experiment´ when it was found out by testing that glass is one of the best materials for radiation walls, that industrial earthenware pipes by geometry and thickness can be used for ´heating sculptures´ or that the air- cavity inside a metal bath tub is enough for heating a bathroom. The whole system was designed that in the cases of growing houses the added spaces could be connected to the heating without hassle. The inhabitants are very satisfied with the comfort of the system and all eleven houses still have the original stove and hypocaust elements.

3.6 the (self-) building activities and reusing/upcycling second hand building parts

The self-building activities of the group were one of the relevant aspects to keep the building costs on the predicted level. A primary challenge was to define the borderline of liabilities: Contractors would not take their legal liability if their work was ´mixed up´ by ´amateur builders´. So the building process needed clear logistics along these borderlines. This included the fact, that self-build activities could not precisely be predicted in terms of needed execution time. Delays could give contractors excuses for follow up delays or asking for financial extras.
Self building in this project included also integrating and ´upcycling´ of used or ´waste´ building parts, long before the notion ´upcycling´ became common language (Fig. 11).

Fig. 11 as one example, the ´nordern corridor´ was built with windows and doors of demolished buildings, giving the entrance area ´second hand aesthetics´. Industrial waste like laser-cut steel plates was transformed into a spatial element (pictures 2015)

The most severe issue in the self building process was the relation between the group and its individual members in terms of equality of contribution. It was obvious that there were big differences in ´productivity´ of different group members due to their skills, building experiences, physical shape and spare time. The group decided that each hour of each member has the same value. All working hours were written in a list and at the end the ones who worked less had to pay a financial compensation to the ones who worked more. This system sounds very simple but it showed several traps[7.]
The group also decided that its members work equally and in all houses and do not prefer their own unit in terms of intensity or precision of the work. All these decisions can be considered as productive, alone the execution and the sanctions in case of non-solidary behaviour are the crux, when a small minority of group members tended to ignore decisions in daily practice. In 2015 during the interviews with six group members it became obvious, how different participation on group activities for self-building shaped strongly positive and life-long personal relations between some neighbours and lead to conflicts with others.

4. Discussion

The results of the process and the use over time must be measured against the original objectives and group agendas of ´communal + self-determined + ecological + low-cost´.

- the statute and the contract for such a project must be extremely clear, including sanctions against violations. The closer the relation or friendship between group members (which is very common), the more essential are precise and legal definitions: (unrealistic) high expectations proved to turn into frustrations when for example self-building revealed contradictions between image and performance of individuals. In this case, the statute was very clear and differentiated but there was not enough clarity about the sanctions in case of infracting it.
- The adaptive design strategies, adaptive in relation to economy, tectonics, family size, amateur building etc. was a key for the success of this dwelling over three decades.
- projects with strong participation and self-building are advised to engage an external (and professional) mediator for conflicts. This should not be the architect nor the building supervisor who is party with conflicting interests in the process.
- ´Ökologische Gemeinschaftswohnanlage Nofels´ had an excessive tendency to support the individualistic. Individual choices along individual budgets should be possible, but the differentiation in standard was too wide for this low-cost project and produced a mountain of extra administration and accounting.
- green spaces do not necessarily stay ´green´ over time
- some ´healthy materials´ showed minor problems: loose bulk cork in floors as thermal insulation was a magnet for noisy field- mice, some died under the floor with 2 weeks of severe smell. This was solved when a significant cat-population was living in different homes.
- self- made earth-insulation or earth-bricks are positive for indoor climate but needed much more time to be produced than the group-members imagined. In general and as a rule of thumb for self-building, untrained amateurs with not optimal tools and fragmented working hours need up to four times longer for the same building activities compared to professional companies !
- A standardization of hypocaust elements with prefabricated chambers would lower the costs and make them a more realistic alternative. In Nofels, experimenting time and development costs were not paid but this idealism cannot be expected in follow-up projects.

After the eighties, by neoliberal tendencies and paralleled stronger individualization of the society, group projects became ´out of fashion´ for some time. The difficulties, extreme efforts, risks and practical problems of some of these groups and their projects supported this tendency. But there are strong signs for a new and advanced generation of group housing projects in Austria and Germany.

5. Conclusion

The project has many layers to learn from: new homes in Austria became less affordable since 1987. Only between 1999 and 2004, the rents for apartments have gone up by 30% or 5,35% year[8] while the general inflation was average only 2%. Their environmental impact has not significantly improved apart from marketing propaganda. Adaptability is still an alien concept for most of the housing market.

´Ökologische Gemeinschaftswohnanlage Nofels´ is a success when looking at its tectonic concept and realization, specifically concerning its performance for the ´growing house´: Seven out of the eleven units have grown over time in different ways, using the various horizontal and vertical offers which were part of the original design.
Further there was no need for major maintenance. Seven of the houses have still the original first colour coating on the wooden facade, there was nowhere a need to replace the low-tech lime plaster.

Despite different life situations, higher incomes and new family situations, the minor fluctuation of the inhabitants is a clear indicator of high user satisfaction, which was also expressed in interviews with the six owners: Out of eleven families, eight are still the original owners. One family sold the house and moved to another place, two couples have divorced and sold the house. One buyer was the son of an original group member, who together with his wife has four young children. Therefore already the third generation lives in the housing estate and after a period of grown up children leaving their parents homes, again small children inhabit and enjoy the place.

The collective design-, decision- and building processes certainly have been exhausting over some periods and provoked conflicts. But over time, the housing group was rewarded with high living quality at extremely low cost for a life time and lasting friendships. Above all: What´s the point to live in a city or town if you don´t interact with your neighbours?

6. References

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[1] Feldkirch is an Austrian border city. It is situated on the border to Liechtenstein and only three km from the Swiss border. The city has 30.000 inhabitants.

[2] Edit Breuss-Mueller, co-owner of house five. Beside Edit Breuss, Joachim Breuss, Gerhard Diem, Edith Diem, Katharina Unterrainer and Christine Herbst were interviewed.

[3] presently, a ´renaissance´ of ´Baugemeinschaften´ (self-determined participatory building groups) can be observed in Germany and Austria. For instance in Hamburg, Berlin, Freiburg, Munich and Vienna, the planning departments have initiated an agency or networks to support these groups.
http://www.stadtentwicklung.berlin.de/bauen/baugemeinschaft/

[4] the average age of the participants when the houses were built was 29

[5] there were 19 children when the group moved in, 14 of them between one and six years

[6] the gas burner heated air and was installed below the wooden burner in a connected cavity

[7] There were problems with the precision and interpretation of time records. The compensation per hour was decided collectively clearly too low, so there was no strong economic incentive to work but rather pay compensation, although this was a minority problem: The compensation should be paid on a monthly base, so there are possibilities for adaptations and change during the building process. At the end of such a building project, the money is gone.

[8] Statistik Austria
http://www.statistik.at/web_de/statistiken/wohnen_und_gebaeude/wohnungsaufwand/betriebskosten/023032.html

A Case Study of Rainfall Water Harvesting Effects on Runoff for Guzelyurt, Northern Cyprus

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Summary

Development of the cities and growing population significantly change the natural water cycle in urban districts and consequently increase the amount of runoff water which results in higher flood risks. For mitigating the negative impacts of urbanization on runoff, rainfall water harvesting (RWH) is proposed and applied in several regions for reducing the amount of runoff. In this study, the RWH by installing storage tanks and the methodology for studying its effects on runoff are introduced. The main objective for this study is to quantify the effect of applying RWH on reducing the pressure on the existing drainage system in order to avoid the necessity of renewing the existing drainage infrastructures. The methodology is applied on a small catchment in East Guzelyurt, Northern Cyprus as a case study, in order to investigate the effectiveness of RWH for this region. The results show that considering a 6 hour rainfall with a critical intensity of 30 mm/hr, for the selected catchment the runoff can be reduced up to ~15% in first 2 hours; however before the peak rainfall, the storage tanks get full and the runoff is not significantly reduced for the next 4 hours. The results show that RWH by installing storage tank in residential buildings for this catchment is not sufficient for reducing the amount of runoff and other harvesting methods should also be considered.

Keywords: Rainfall water harvesting, sustainable development, source control, peak discharge.

1. Introduction

Under natural conditions water cycle includes precipitation, infiltration, surface runoff and evaporation. Development of the cities and growing population significantly change the natural water cycle by mainly interfering in evaporation and infiltration stages; hence higher amount of runoff water would be exposed to the conventional water management systems. The changes in water cycle not only increase the flood risk but also adversely affect the quality and quantity of the available water for different applications. The main reason for having higher runoff is the impermeable surfaces in the cities, causing lack of infiltration and rapid discharge to the public drainage system. Comparing to the rural district in which impervious coverage may only be 1% to 2%, in urban areas these numbers would increase to 10% in low density urban, 50% in multi housing communities, and 90% in dense metropolitan areas [1]. This defected cycle finally results in negative impacts on ground water recharge, the quality and quantity of water and urban climate. The quantity impact refers to increasing in flood peak and flood volumes and quality impact is associated with the higher pollutant in runoff in comparison with secondary treated domestic wastewater [2]. In addition, recent observations on climate change are another challenge for stormwater management in urban areas. As a result of the global warming, unusual extreme events are happening at different locations on the earth and the conventional systems are unable to manage them. The conventional water management systems are not designed for such extraordinary extreme events and this increases the risk of flooding, hence it is clear that the conventional water management systems are neither sustainable nor adaptable to the climate change [1].

Considering all these issues shows an increasing demand for sustainable development in cities and necessity of a real change in water systems infrastructures. For mitigating the negative impact of urbanization on water cycle and ecology, a sustainable and decentralized water management is highly demanded. Rainwater Harvesting (RWH) is one of the common techniques of the decentralized method for stormwater management which has practical advantages in reducing service demand and consequently diminish the cost throughout the time by saving resources and energy [1]. In other words, it is a promising approach towards supplementing water scarcity in areas that water resources are inadequate. There are several studies on investigating advantages and disadvantages of applying RWH as a sustainable solution to conventional water management systems.
In a study done by Aladenola and Adeboye in (2009) [3] it is stated that by harvesting rainwater in Abeokuta it is possible to meet the monthly demand for flushing and laundry in residential area except in December, January and February. Moreover, it is mentioned that the highest potential for water harvesting is in June and September which is the rainfall peak period in Southwest Nigeria. In another study done by Petrucci (2012) [4] the effect of rainwater harvesting on runoff is analyzed to investigate the potential of RWH technique for stormwater source control. In an urban catchment with 23 ha area in east of Paris, 1/3 of the private parcels have installed rainwater tanks and the rainfall and runoff were measured before and after tank installation. The results showed that the installed rainwater tanks could affect the runoff for usual rainfall events but are too insufficient to prevent sewer overflows in case of heavy rainfall events. Additionally, in a study that investigated the rainwater utilization in Germany which is done by Herrmann and Schmida (2000) [5] the objective is mentioned as quantifying the effect of rainwater usage on urban drainage system and the results showed that rainwater usage system can significantly reduce the water consumption and drainage water. In addition, for overflow events it is mentioned that the high specific service water consumption which mainly occurs in multi-story buildings and high population density will lead to reducing or even eliminating overflow runoff. Gilory and MacCuen, 2009 [6], investigated the effects of location and quantity of cisterns and bioretention pits on stormwater runoff for various return periods and different land uses. They suggested the general trend for locating cistern and bioretention as:

- The importance of efficient volume in controlling peak discharge.
- Locating bioretention in drain pervious surface would be less effective than impervious areas due to partial reduction in runoff rates and volume in grassy areas.

- Effectiveness of cistern and bioretention are highly dependent on the return period of the storm event.
- In large impervious areas with high intensity of rainfall cistern and bioretention should be located in series while for small areas and frequent events it is better to locate them independently.
- Design volume for cistern and bioretention can be based on controlling peak discharge or volume controlling [6].

In another study for investigating the effectiveness of RWH for Northern Cyprus, Okoye et al (2015) [7] investigated the optimum tank size of a single residential housing unit for rainwater harvesting. They considered a specific rainfall profile, a constant water consumption rate per capita and an assumption of average rooftop area and performed their analyses based on linear programing. The proposed model was applied on the cities in N. Cyprus and the feasibility of applying RWH as a solution for rehabilitating depleting aquifers has been investigated.

In the current study, the methodology for investigating RWH by installing storage tanks for the residential buildings in small catchments is introduced. This methodology is general and can be applied on any region if the data are provided. In this study, a small catchment in East Guzelyurt, N. Cyprus is investigated as the case study for the introduced methodology. Guzelyurt is a small city with 19800 population and old urban design which has a conventional separated sewerage system. This area recently faced flood situation in urban areas and caused serious problems such as damaging the buildings and main roads. The last flood situation happened in this area was in January 2010 after a dry period which was observed in Cyprus in 2007 and 2008. The sewerage system in this city has not been designed for such extreme events and needs some retrofits. Moreover, not only discharging water from urban area is an essential process, but also harvesting this water for different purposes is required since this area is suffering from water shortage and decreasing water ground level. The methodology introduced in this study is based on a typical rainfall pattern and the assumption of constant water consumption per capita.

2. Methodology

To accomplish the objective for this study and find the effects of applying RWH techniques on the runoff water generated from a small catchment, it is necessary to investigate the catchment surface characteristics, rainfall characteristics and water consumption of each dwelling. A small catchment located at East Guzelyurt which includes different land use characteristics is chosen to be studied based on the methodology given in this section. This catchment is selected since the required data for this study were available for it. The characteristics of the catchment are analyzed and the total amount of runoff water from the studied area is calculated based on rational method [8]. The rainfall characteristic of the region is assumed to be compatible with 6 hour rainfall SCS type II hyetograph [9]. Additionally, the dwellings in the residential section are categorized into 6 batches based on the rooftop area sizes. For simplicity of the study, the water consumption is assumed to be constant and different tank sizes are used for different dwelling categories.

2.1 Analyzing the studied area

Figure 1 shows the selected catchment for this study which is located at East Guzelyurt. The area of the catchment is 491193 m^2 and the average slope is 1%. This area has not been completely overtaken by constructing buildings yet and the main portion of the catchment is orange gardens and bare lands. The characteristics of the catchment is investigated by developing the orthophoto map using AutoCad software. The ortophoto map is developed by integrating the photos from

Google Earth software and the road map of Guzelyurt. Based on the developed orthophoto map the rooftops were selected individually as shown in Figure 1. Moreover, the statistical analysis for finding the number of dwellings in each rooftop category is performed using Arc GIS software. In addition, the surface characteristics in different parts of the catchment are also identified using the generated ortophoto.

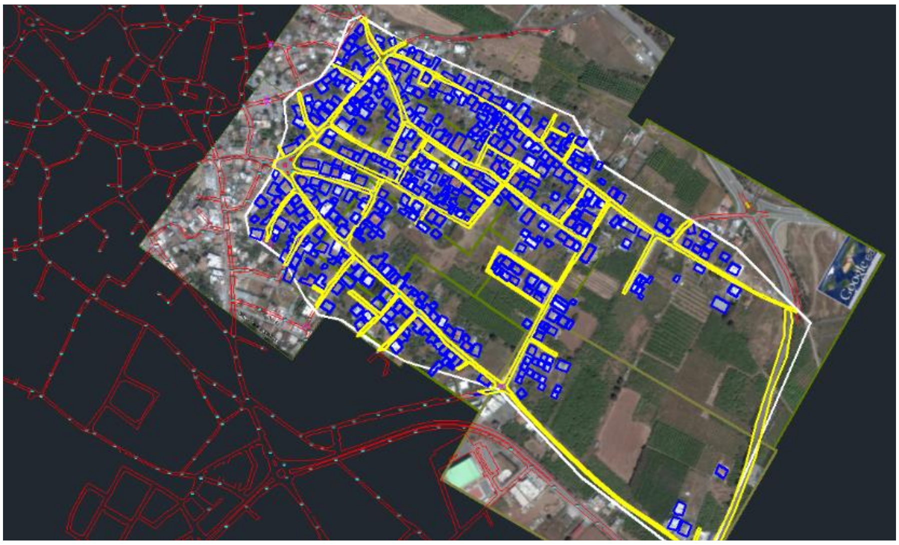

Figure 1. Dwellings are categorized based on the rooftop size for the selected catchment, Guzelyurt, N. Cyprus

2.2 Rainfall characteristics

The rainfall hyetograph is synthetically generated using 6 hours SCS type II hyetograph [9]. The critically high rainfall intensity is assumed as 30 mm/hr based on the precipitation characteristics of Guzelyurt which is obtained from the measured data provided by the local authority, and the total rainfall is calculated for a 6 hour period. Using these data as the input the hyetograph is generated in order to illustrate the rainfall intensity at each time step.

2.3 Runoff from the catchment

According to the surface characteristics of the catchment area which is analyzed by using orthophoto maps, different subareas are listed based on their surface properties and land use and the runoff coefficients for each subarea is determined in order to use the rational method. Moreover, the peak runoff is computed using Equation (1) [8]

$$Q_P = 0.278\, i \sum_{j=1}^{n} C_j A_j \qquad (1)$$

where Q_p is the peak flow rate in m^3/s, i is the average rainfall intensity in mm/hr, A is the drainage area in km^2 and C is the runoff coefficient which is dimensionless.

2.4 Runoff from roof tops

The volume of rainwater that could be harvested from rooftops is determined using Equation (2) [10],

$$VR = \frac{R \times TRA \times R_c}{1000} \qquad (2)$$

where VR is the volume of rainwater in m^3 in specific time step, R is the rainfall intensity in mm/hr, TRA is the total roof area in m^2, R_c is the runoff coefficient and 1000 is the conversion factor from mm to m.

2.5 Consumption

Based on a study done by Okoye et al [7], consumption in Cyprus is 0.125 m^3/day per capita. Since in this study the consumption is assumed constant at each time step hence, the daily consumption is converted to hourly consumption by dividing it to16 hours of water consumption per day assuming that water consumption is negligible for 8 hours in 24 hour. Additionally, for calculating the total consumption in the region at each specific time step, it is assumed that the number of residents per each dwelling is 5. The total consumption for each sub area is calculated by finding the total population in the subarea and multiplying by the consumption per person.

2.6 Water harvesting

It is assumed that the RWH is applied using storage tanks for each dwelling at the sub catchment. The rooftops of the dwellings in the region are categorized six different batches according to their area. Different storage tank sizes are selected for each batch based on the most frequent rooftop area in it. Considering specific tank sizes, cumulative amount of the water that can be harvested is calculated while there is a constant consumption for each time step. This calculations are continued till the tanks get full and then the runoff from the rooftops are considered to be disposed to the sewerage system.

3. Results

3.1 Characteristics of the sub catchments

The results from investigating the orthophoto map of Guzelyurt show three types of land use for this catchment which are presented in Table 1. The residential part is only 17% of the whole area while the street and paved area are about 10% and 73% of the area is mainly fruit gardens, bare land and wheat fields which are categorized as neighborhood area. The runoff coefficient for each of these characteristics are extracted from typical coefficients for design with 5 to 10 years frequencies (ASCE,1970) [8]. Moreover, the highest value for the range given for streets, asphalt and neighborhood area is considered as a runoff coefficient to maximize the confidence level of the study. The runoff coefficient for the rooftops in Guzelyurt is adapted from [7].

Table 1. Results for surface characteristics of the catchment

Category of the surface	Area (km^2)	Fraction of total area	C coefficient range	C	Q_p (m^3/s)
Roof tops	0.09	17%	.75-0.95	0.9	0.57
Streets, Asphalt	0.05	10%	0.7-0.95	0.95	0.38
neighborhood area	0.36	73%	0.5-0.7	0.7	2.09

The total number of dwellings that is recognized from the photomap is 441 units which are categorized in 6 series as shown in Table 2. As it is shown in the results, 44% of the dwellings are in the range of 100 m^2 to 200 m^2 and most frequent area in this range is the dwellings with 100 m^2 area. Based on the most frequent area size in each batch, different tank sizes are considered to be installed and the values are given in the table. The total installed tank size would be 2180 m^3.

Table 2. The categories for the dwellings

	Area range for each category					
	<= 100	100<A<=200	200<A<=300	300<A<=400	400<A<=500	500<A<=600
Number of dwellings	72	194	111	43	14	7
Fraction of the total (%)	16%	44%	25%	10%	3%	2%
Most frequent area (m^2)	75	100	200	300	400	540
Tank size (m^3)	2	5	5	7	10	10

3.2 Hyetograph

The volume which was deducted from the whole runoff by RWH is calculated and the equivalent rainfall is obtained by deviding the total harvested water volume by the total area of the catchment. The resulting hyetograph after RWH is compared with the hyetograph before RWH which is shown in Figure 2. Since the rooftop area is just 17% of the whole catchment the reduction in runoff is not significantly high, especially for the time when peak rainfall intensity occurs. Considering the total runoff in 6 hours RWH from the rooftops reduce the rainfall intensity by 2% in six hours of rain fall. Additionally, Figure 3shows the percentage of reduction in each time step of the rain fall. After nearly 2 hours of rainfall the tanks get full and since the consumption is not significantly reducing the stored water, the reduction in runoff drops significantly. After 2.7 hours the tanks are completely full and there is no reduction in runoff. This shows the fact that similar to the results of the study performed for RWH at a region in Paris [4], RWH in the storage tanks would not reduce the runoff water significantly in case of high rainfalls with high intensity at this catchment. Nevertheless, the possibility of RWH in small ponds for harvesting higher amounts of rainfall water should also be studied.

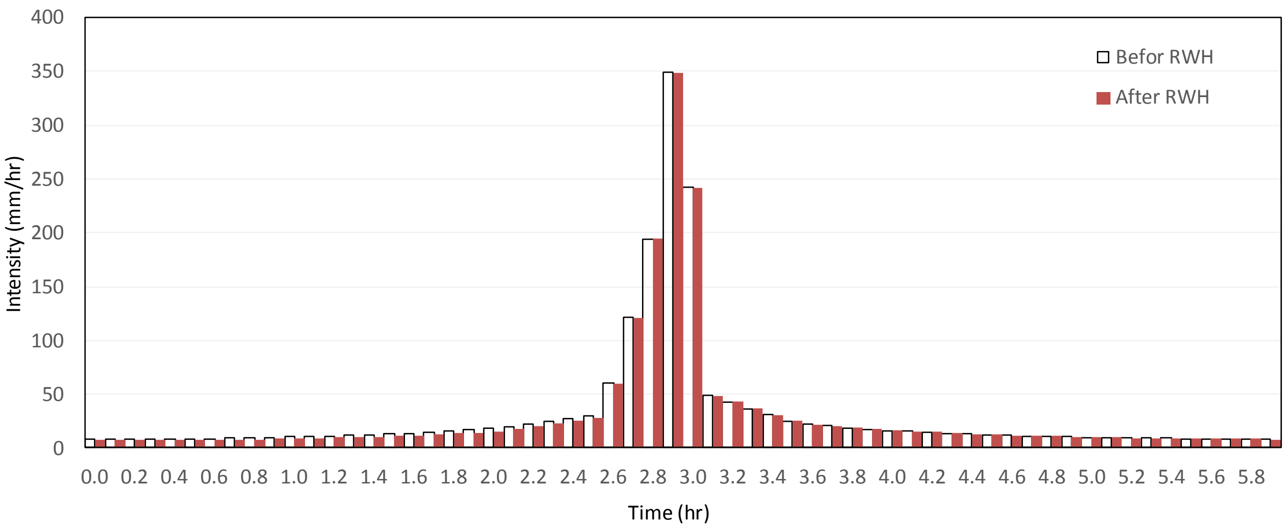

Figure 2. The hyetograph before and after rainfall water harvesting from the rooftops

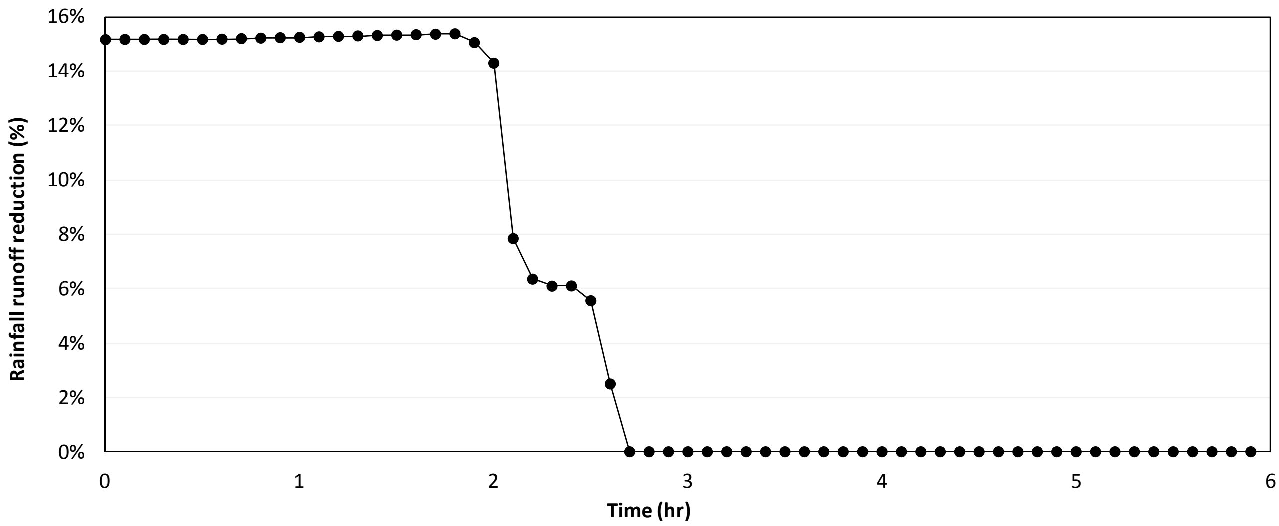

Figure 3. The reduction in the runoff after applying rainfall water harvesting from the rooftops

4. Conclusion

The effect of applying RWH in a small catchment on rainfall runoff volume was assessed. The dwellings in the catchment are categorized into 6 batches based on the rooftop size and different storage tank sizes are considered for each batch. The methodology was presented and applied to a small catchment in East Guzelyurt, N. Cyprus. Results show that only 16% of the runoff from rooftops is harvested considering 2180 m^3 installed tanks for the dwellings in the catchment. The rooftops are only 17% of the total area in the catchment and the fraction of harvested runoff would increase by escalating the tank size for each dwelling. Considering the small fraction for rooftop area, the reduction in rainfall intensity after RWH was only 2%. The results show that in order to influence the reduction in the amount of runoff water considerably, it is necessary to study and apply other methods for rainfall water harvesting including the construction of larger storage capacities. These storages can be constructed as the components of urban design such as ponds for the cities and recreational areas. In addition, the effects of urban developing and land use change on runoff volume would be investigated as the future study.

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A Comparison of How Sustainability and Green Building Standards are being adopted into Building Construction Codes within the United States and the EU

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Summary

Sustainability is being adopted into building codes at different levels of government and with varying motivation. The approach taken reflects local societal perceptions, political priorities, national policies and economic factors. One early contributor to this process was the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) program. LEED was setup as a voluntary program intended to transform the industry and can be seen as a success by a trend of including sustainable design practices in building codes around the globe. The International Green Construction Code (IgCC) is the basis for which most U.S. states can include sustainability in their building codes, although there are exceptions. California, for example, has developed its own program (CALGreen). The IgCC contains two options for compliance; the second being the application of ASHRAE Standard 189.1, managed and developed by ASHRAE, USGBC and the Illuminating Engineering Society. The adoption of energy performance standards also varies widely across the U.S., while in contrast the EU is moving towards nearly zero energy buildings at the end of this decade per various directives like EPBD and EED. The next several years will see further modification in this process in the U.S. as the IgCC and Standard 189.1 will be merged. This paper describes and compares the current status and trends of 'sustainable' building codes adapted by individual political entities within the U.S. and the EU.

Keywords: High performance buildings, ASHRAE 189.1, LEED, EPBD, EPC

1. Introduction

1.1. Purpose of green building rating systems, standards and codes

During the past 20 years or so a movement has grown to develop programs that will help encourage and provide guidance in the inclusion of sustainability measures in the design, construction and operation of buildings. Initially, these programs were setup as measures by which a building project could voluntarily participate and achieve recognition for including recognized sustainability concepts in the design. As the concept of 'green buildings' began to take hold, some jurisdictions began to look for methods to make these sustainability measures mandatory rather than just voluntary. Thus began the quest within those organizations that develop and write standards and building codes.

The creation of standards or codes that will define a level of performance that must be achieved before a building could be referred to as ‘green’ or sustainability-focused was thus identified as a need within the industry. Due to the wide variation in economic, social, political and technological conditions between the various countries and jurisdictions of the world, it is not surprising that there will need to be a wide variation in the approach taken if we want to truly achieve the goals of moving sustainable building design into the mainstream. This paper provides a brief synopsis of the process that has occurred in this development and a description of the state-of-the-art in the industry, particularly focusing on the United States and Europe and comparing the development in these two regions. Various types of sustainability programs exist that are categorized as follows:

Rating Systems - A green building rating system is intended to provide a method whereby a building project (or existing building owner) can voluntarily adapt a set of sustainability measures that meet a pre-defined set of requirements. Examples of relevant green building rating systems include BREEAM (Building Research Establishment Environmental Assessment Method) [1], LEED (Leadership in Energy and Environmental Design) [2] and GreenGlobes [3], which are discussed in Section 2.

Guidelines – A green building or related guideline is a set of criteria that an outside entity has defined as being design criteria or goals that the project should look to incorporate into their project to minimize the overall environmental footprint of that project. Examples include the Advanced Energy Design Guidelines (AEDG) that ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers) has produced with the backing of the U.S. Department of Energy [4].

Standards - A Standard is a collection of criteria that are recognized within the industry as meeting the acceptable requirements for a level of performance. The purpose of a Standard may be for adoption as the basis of a building code, or just a level of performance by which a project should be designed toward, i.e. ASHRAE Standard 90.1 [5] that is the basis of the energy codes within the U.S.

Building Code – While the building permit and code compliance process varies widely across the globe, there are some common factors. First, a minimum set of criteria must be established. These criteria can be prescriptive or performance in nature. Prescriptive criteria are specific items and/or specific methods to meet to demonstrate compliance, while performance criteria specifies a goal to be reached and may be more involved, i.e. requiring building energy simulation modelling to demonstrate compliance.

1.2. Brief history of green buidling programs in the U.S. and EU

Various rating systems that have been developed by organizations around the world that strive to indicate how well a building meets prescribed requirements and to determine whether a building design is green and to what level. They all provide useful tools to identify and prioritize key environmental issues. These tools incorporate a coordinated method for accomplishing, validating, and benchmarking sustainably designed projects. As with any generalized method, each has its own limitations and may not apply directly to every project’s regional, political, and owner design-intent-specific requirements.

Building rating systems, e.g. LEED and BREEAM, are used throughout the world [6] to assess and rate a building’s environmental performance by awarding some form of “credits” for various categories (e.g. environment, society, economy). Depending on their features, there are several pros and cons [7]. Other efforts also focus on labelling the buildings' energy performance, which are discussed later. Information on worldwide practices for building energy performance ratings and disclosures, examples of labels and certificates are available from [8].

2. The U.S. Path to Date

2.1. The U.S. Green Building Council's LEED rating system

The rating method primarily used in the United States is the Leadership in Energy and Environmental Design (LEED) program [1]. A LEED Silver certification is required by at least 16 states for public buildings and any LEED certification is a required option for state buildings in a majority of states [9]. LEED was created by the U.S. Green Building Council (USGBC) in 1998 as a voluntary, consensus-based, market-driven green-building certification system. It evaluates environmental performance from a "whole-building" perspective over a building's life cycle, providing a numerical standard for what constitutes a green building. LEED has been applied to numerous projects over a range of project certification levels, and its use has grown rapidly over the past several years. Rating systems have been developed for a variety of specific building types (e.g. building core and shell, and commercial interiors for project developers and tenants (respectively), as well as schools, retail, hospitality, data centers, warehouses and health care, and homes).

2.2. ASHRAE Standard 189.1 and the International Green Construction Code

Soon after the LEED program was initiated in the U.S., some jurisdictions began to include achieving LEED certification (of a specific level) as part of their building permitting and code process. This was never how LEED was structured, and thus in 2006, ASHRAE (in conjunction with the USGBC and the Illuminating Engineering Society (IES) began a process to create a standard that would address a growing need within the industry for a code-language document for green buildings suitable for adoption as part of building codes. The ASHRAE 189.1 Standard for the Design of High-Performance Green Buildings [10] was developed during a more than three-year process with extensive public review and was initially published in early 2010. This Standard includes mandatory criteria in all topical areas (e.g. site, construction, materials, energy, IEQ, water,) and provides for two compliance paths. The prescriptive path includes simple compliance criteria; simple in the sense that they are more like a checklist of technologies or system requirements. The performance path is more complicated in that it requires additional analysis to verify that compliance is indeed achieved. Soon after the initial release of Standard 189.1, ASHRAE and the International Code Council (ICC) reached an agreement whereby the standard would be included as an appendix to International Green Construction Code (IgCC). The IgCC [11] is a model code that includes sustainability measures for the entire construction project and its site, i.e. from design through construction, certificate of occupancy and beyond. It was released in March 2012 and it specifies Standard 189.1 as one compliance option. The project team has a choice for compliance: they can comply with the IgCC or with Standard 189.1. In the U.S., it is the codes developed by the ICC that are what the various states and local jurisdictions adopt as their building codes.

2.3. Other green building rating systems and codes

Another rating method being used in the U.S. since 2005 is the Green Globes program [3]. It was based on the Canadian Green Building Initiative (GBI) to promote green building guidelines for residential buildings that, in turn, like LEED, was originally based on the UK BREEAM rating system (discussed in section 3.1). While both aim to help a building owner or designer develop a sustainable design, Green Globes is primarily a self-assessment tool (although third-party assessment is an option) and also provides recommendations for the project team to follow for improving the sustainability of the design.

In 2010, the state of California adopted its own state-wide green buildings code, termed CALGreen, and an updated version issued in 2013 went in effect in January 2014 [12]. One unique item of CALGreen is that there are criteria for both residential and non-residential buildings in the same program. In most other situations in the U.S., residential and non-residential building codes are based on separate documents and standards. CALGreen also contains a combination of both mandatory and voluntary measures for each category of building.

One additional building rating system to mention in the U.S. is the Energy Star program for buildings. For a commercial building to earn the Energy Star designation, the building is first rated using an online “Portfolio Manager” tool [13]. The Portfolio Manager system is the rating tool of choice for several cities that require energy benchmarking (e.g. New York, Seattle and Boston, as discussed in Section 2.5), as well as the Canadian government’s national energy benchmarking program.

2.4. ASHRAE bEQ rating system

ASHRAE's Building Energy Quotient (bEQ) [14] is a new building energy labelling program that allows the industry to focus on opportunities to lower building operating cost and make informed decisions to increase value. This program was fully launched in 2014. The bEQ label includes the "As Designed" rating of the building’s potential energy use, and the "In Operation" rating of the building’s actual measured energy use as influenced by the building’s occupancy and use.

The bEQ program provides information on the potential and actual energy use of buildings. This information is useful for: building owners and operators to compare against peer buildings; building owners to differentiate their building from others to secure potential buyers or tenants; potential buyers or tenants to gain insight into the potential long-term building cost; and operations staff; e.g. to inform their decisions regarding maintenance activities.

2.5. Energy benchmarking and reporting

Similar to the adoption of green building codes, it is at the U.S. city level that most of the energy benchmarking and reporting requirements have been implemented. A growing number of cities in the U.S. now require some form of energy reporting and benchmarking for commercial buildings. As of mid-2015, approximately 15 major cities across the U.S. have adopted some form of energy reporting in their local ordinances (Fig. 1). This trend was first started by several cities in the Northeastern U.S., i.e.. New York City and Boston, but has also spread to other cities. Interestingly, these cities are in regions not always known for being at the spearhead of energy efficiency initiatives, e.g. Atlanta, Georgia and Kansas City, Missouri. While differences exist in the local ordinances as far as the size and type of buildings for which they apply, the rationale used often is a combination of overall city level energy efficiency as well as the potential for local job creation for energy auditing.

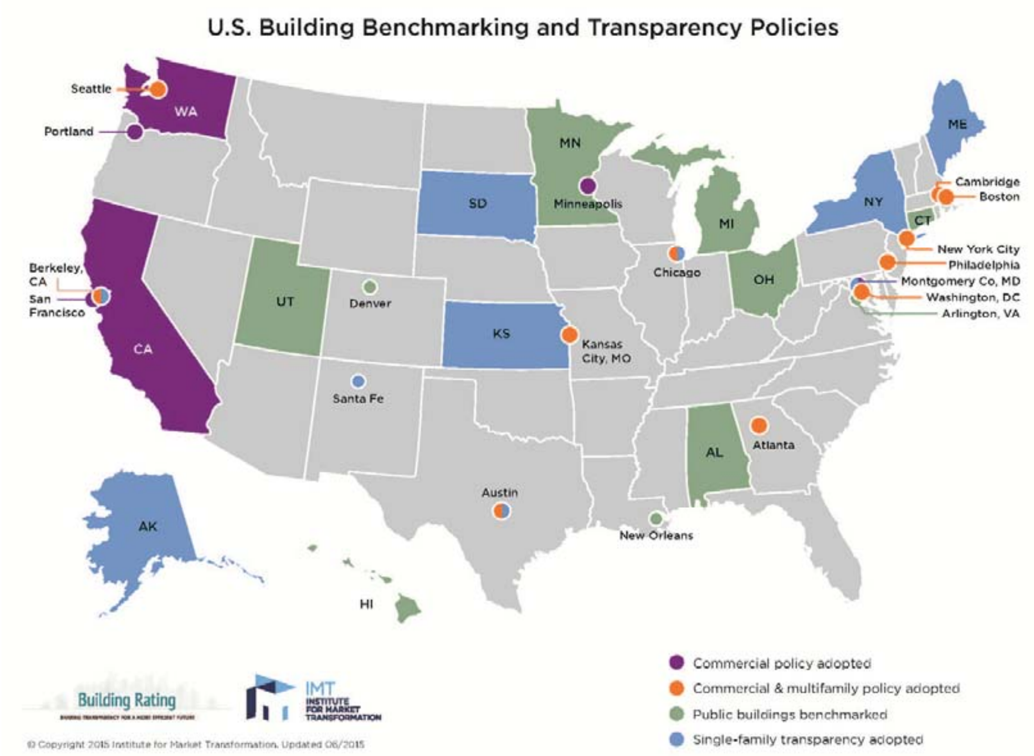

Fig. 1 U.S. cities and states adoption of building energy benchmarking policies [8]

3. The EU Path to Date

Various voluntary schemes have been introduced in the Europe over the years. Amongst them, the most notable effort has been the BREEAM method, a voluntary program first introduced in the U.K. Parallel efforts by the European Commission over the past decade have also introduced several mandatory directives to increase efficiency at all stages of the energy chain, targeting final consumption and the building sector, where the potential for savings is greatest.

3.1 BREEAM and other rating systems

The green building movement was spearheaded with the introduction of BREEAM by the Building Research Establishment (BRE) in the U.K. as an environmental assessment method and rating system in 1990. This is a voluntary, consensus-based, market-oriented assessment program to assess any type of building or large-scale communities anywhere in the world. With one mandatory and two optional assessment areas, BREEAM encourages and benchmarks sustainably. The mandatory assessment area is the potential environmental impact of the building; the two optional areas are design process and operation/maintenance. To date, over 425,000 buildings have been certified. Nationally, specific local schemes are available in Germany, Norway, Sweden, Spain and The Netherlands. Other notable rating systems in the U.K. include the Global Environmental Method (GEM) program, which is a version of the U.S. Green Globes. In Germany, the passive house concept has evolved to an international association for standardizing the design and construction of low energy buildings. Space heating energy demand drops to 15 kWh/m² even in moderately cold climates, with a total primary energy consumption of 120 kWh/m^2. Similar concepts and labels are also introduced in France (e.g. Effinergie) and Switzerland (e.g. Minergie), which are most popular for residential buildings.

3.2 Development of the EPBD

Over the past 20 years, numerous European directives have been issued to address different aspects of energy use in buildings, starting with hot water boilers and household appliances, until, in the early 2002, the first comprehensive policy addressing building energy performance (EPBD) was enacted (Fig. 2).

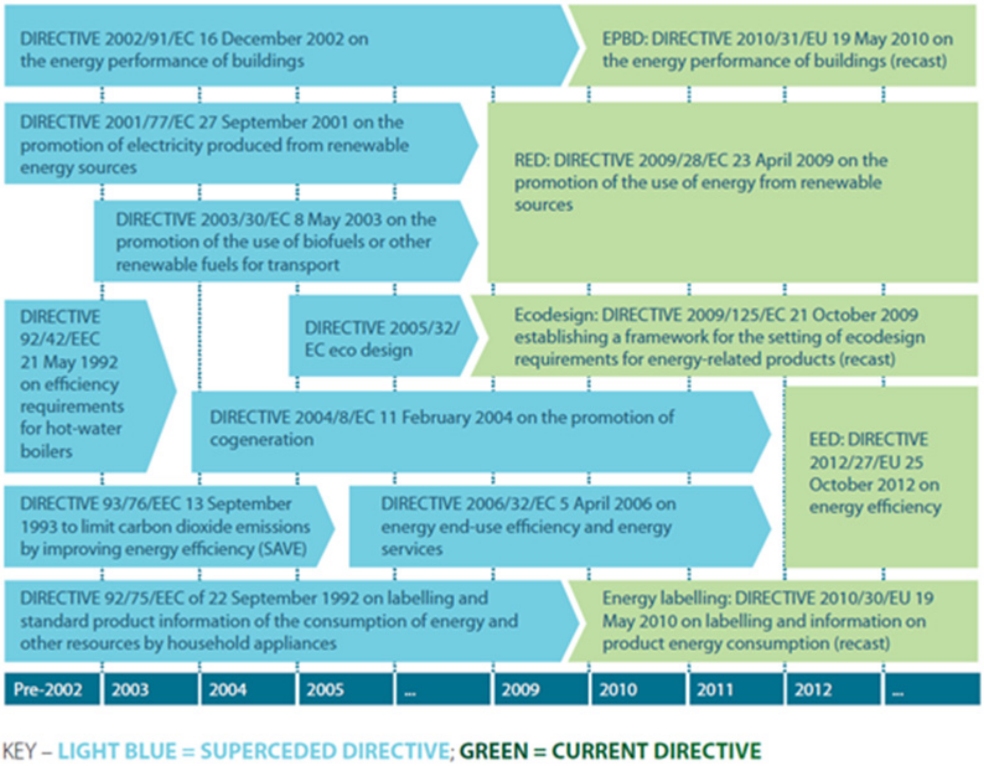

Fig. 2 Timeline of key EU legislation affecting energy use in buildings [15]

The European Directive 2002/91/EC on the energy performance of buildings (EPBD) and its recast (Directive 2010/31/EC) are driving the efforts for improving the energy efficiency of the European building stock. Accordingly, European Union Member States (EU MS) are strengthening the energy performance requirements and set more stringent goals for reducing the energy performance of buildings. By the start of 2021, all new buildings shall be “nearly zero-energy buildings” (NZEBs), while new buildings occupied / owned by public authorities should comply by 2019. For NZEBs, the nearly zero or very low amount of energy required should be covered to a very significant extent by on-site or nearby renewable energy sources (RES).

Austria, Denmark, Germany and Sweden have emerged as successful leaders in adopting and implementing the EPBD into national initiatives to promote green buildings. This is well aligned with the EU 2020 targets: a reduction in EU GHG emissions of at least 20% below 1990 levels; an increase to 20% of RES contribution to EU’s gross final energy consumption; a 20% reduction in primary energy use by improving energy efficiency.

A recent technical assessment [16] of the national/regional calculation methodologies under the EPBD provisions has revealed that not all EU MS have a complete set of calculation methods for evaluating the energy performance of buildings and only about half of them are in-line with the European standards prepared by the European Committee for Standardization (CEN) to support EPBD implementation. Only 53% of the methodologies are considered fully reliable for the calculation of the primary energy demand given that the primary energy is not used as an energy performance indicator, the number of primary energy factors is low and not all buildings' technical systems are addressed. These issues reveal some inherent problems of the EU transnational efforts for EPBD implementation. At the same time, the second-generation CEN standards are under development, and these also are planned to be published as EN-ISO standards [17].

3.2.1 EPCs for Energy Benchmarking & Reporting

Energy performance certification (EPC) of buildings, in accordance to EPBD, is an ongoing process for several years throughout the EU MS. EPCs document the building's energy performance that is usually expressed as an index in terms of energy consumption, carbon dioxide emissions or energy cost per unit of conditioned floor area to facilitate comparison between buildings and allow for benchmarking based on distinct energy classes. Various examples of European EPCs and the ASHRAE bEQ label are available in [18]. The main information provided in an EPC is an easy-to-understand global indicator of the building's energy performance expressed as a ranking energy label (building class). It is usually based on the calculated primary energy consumption, although different national calculation methodologies have been adopted by some EU MS, e.g. CO_2 emissions or energy cost.

At a minimum, all new buildings throughout Europe should have an EPC that demonstrates that the building meets the minimum energy performance requirements and is better than a minimum indicator. EPCs in some countries (e.g. Austria, Greece, Ireland, Netherlands, Portugal, Slovenia) provide for an energy performance division into sub-classes, e.g. A+ and A- or B+ and B, thus illustrating even small scale improvements that would otherwise not be evident, to further encourage and differentiate buildings towards the high end energy performance.

3.3 Other EU efforts

The Energy Efficiency Directive (EED 2012/27/EU) establishes a common framework of measures for the promotion of energy efficiency at all stages of the full energy chain, i.e. transformation, distribution, consumption. This is done by setting specific obligations schemes and policies to improve energy efficiency in all end-uses, ensuring a 3% renovation rate of public buildings and a long-term national strategy for building renovation which informs and empowers consumers. The specific targets aim to achieve an overall national indicative energy savings target of 9% by 2016 compared with the average final energy consumption for the five-year period of 2001-2005. This is to be reached by way of energy services and other cost-effective, practicable and reasonable energy efficiency improvement measures. The main areas for potential energy conservation include the building sector and especially energy end-use efficiency in the public sector, EPBD implementation and promotion of energy end-use efficiency and energy services, e.g. energy service companies – ESCOs and third party financing - arrangements.

Several European countries have set minimum levels for the use of energy from RES in buildings, to comply with the RES Directive 2009/28/EC on the promotion of the use of energy from renewables. The total share of renewable energy in the EU in 2012 was 14.1%, up from 8.7% in 2005. The latest report from 2015 states that 25 of the EU countries are expected to meet their 2013/2014 interim renewable energy targets. In 2014, the projected share of renewable energy in the gross final energy consumption is 15.3%.

4. What the Future Holds (or Might Hold)

It is difficult to make a good side-by-side comparison between the various programs in the two regions, as there are a wide variety of program types for consideration. Due to these varied differences in goals and societal concerns in the various countries on both sides of the Atlantic, making broad generalizations about the future are just guesses. In fact, in recent years there has been some pushback in some states to rollback or delay the adoption of energy standards with increasing levels of stringency. This section provides insight on a few trends or changes that are fairly certain to happen in coming years.

4.1 The evolution of green building code and energy ratings in the U.S.

The existence of two different options for demonstrating code compliance with green building standards within the U.S. has led to some confusion. In 2014, ASHRAE and the International Code Council (ICC) reached an agreement that there should be a merger of Standard 189.1 and the IgCC. According to this agreement, ASHRAE would take over the leadership in the technical content and the ICC would provide code language introductions to a merged document. This merged standard would be the best of both organizations' products; containing the technical content as originated by ASHRAE as well as the code 'smarts' brought by the ICC. The plans are for a merged standard/code to be ready for the upcoming 2018 code revision cycle; code revisions by the ICC are on a 3 year rotation basis, with the most recent versions issued in 2015.

ASHRAE is also working on much needed Standard (214P) for determining a building's energy performance in a rating (and labelling) program. This is still in the early development stage and should help to standardize how energy performance is being reported.

4.2 The 2020 EU Targets and Beyond

The initial EPBD impact assessment estimated a reduction of 5-6% of the EU final energy consumption and 4-5% of EU total CO_2 emissions savings in 2020 [19]. Overall, the first National Energy Efficiency Action Plans (NEEAP) has revealed many weaknesses. The majority of them show low ambition and fail to demonstrate credibly how the mandatory energy savings targets will be reached. The shining stars are the plans from Denmark and Ireland that provide a credible and meaningful case for how savings targets will be achieved [20]. The tough challenge that EU MS are facing is the race to comply with the 2010/31/EC EPBD recast that calls for NZEBs by the beginning of the new decade (i.e., as of January 2021). Progress has been slow and there are still a considerable number of formidable challenges for national transposition and interpretation, even in terms of defining national NZEB concepts. Some available definitions of NZEBs are summarized in [21]. Most of them use primary (source) energy for benchmarking and differentiate for residential and some common types of commercial buildings, but there is no consistent definition and the energy use intensities exhibit significant variations.

The share of dwellings that were built prior to 1980 and the widespread adoption of energy performance regulations average about 68% in the EU MS. From an energy performance point-of-view, this constitutes a grim reality and clearly implies that the majority of European buildings will need some kind of refurbishment to meet the new energy efficiency standards for buildings. To support these efforts, an ongoing European project (EPISCOPE) [22] is currently working to develop a conceptual framework to assess national efforts for meeting the EU and national energy and CO_2 savings targets at specific landmark periods, i.e. 2020, 2030 and 2050.

4.3 Looking into the Future

No binding energy targets for the entire U.S. exist, although ASHRAE has been studying what levels of energy performance could and should be targeted. An ASHRAE Presidential committee in 2010 determined that a target site energy utilization index of 139 MJ/m²-yr could be achievable by the year 2025 [23]. This value includes a combination of maximum technology for energy efficiency and cost-effective installation of photovoltaics, and the number represents an overall average for the U.S. building sector and climate zones. While not official ASHRAE policy, this represents a potential target that the Standard 189.1 for High Performance Green Buildings may work to achieve.

The EU is expected to achieve energy savings of 18-19% by 2020, missing the 20% target by 1-2%. However, if EU MS implement all of the existing legislation on energy efficiency, the 20% target can be reached without additional measures. According to the European Commission [24]: for the EU building sector, the cost effective emission reduction by 2050 accounts for an 88-91% decrease of GHG emissions compared to 1990 levels; this will be mainly due to "significant reductions in required heating from improved insulation and greater use of electricity and renewables for building heating as well more energy efficient appliances".

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A Design for Improved Natural Ventilation in Housing Development in Thailand

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Summary

Natural ventilation provides free cooling. However, the use of natural ventilation in a housing development is challenging due to the grid alignment of land lot with the result that the wind is blocked by the houses upstream. This study improved the potential use of natural ventilation in the housing development in Thailand with the following 2 steps: housing setback arrangement and function adjustment. After the housing setback was adjusted into staggered grid alignment, the average air velocity measured in the tested house was increased by approximately 61.7%. However, when looking into the house interior on the level of room function, the air velocity in living and dining rooms were typically low with approximately 0.3 m/s since toilet, kitchen, and stair blocked the wind. To encourage more natural ventilation in those spaces, toilet, kitchen and stair were flipped into another side of the house. The air velocity in living and dining rooms were improved significantly by 33% and 42%, respectively and increase to more than 0.4 m/s which prove to be thermally comfort for Thai people. With the limited design in land lot alignment, the natural ventilation in housing developments can be improved by housing setback arrangement and function adjustment.

Keywords: Natural ventilation, Computational Fluid Dynamics, Housing setback, Air velocity

1. Introduction

Natural ventilation (NV) strategy can offer free and effective passive cooling, reduce the use of air-conditionings systems, an active cooling approach, and improve indoor environmental quality. For tropical country likes Thailand, about 90% of urban indoor environment are air-conditioned due to air and noise pollution [1]. However, in the suburban area, especially around Bangkok the metropolitan, the micro environment around the house is still less polluted. People choose to open air-conditioning only during hot hours of the days. Hence, providing more natural ventilation for the house would help reduce the use of electricity for air conditioning.

In Thailand, air-conditioning system has been used in almost 50% of municipal households and contribute for over 70% of total electricity load in a small household [2]. Most of the houses in modern suburban area are housing development project. It is with challenge to use natural ventilation due to the grid alignment of land lot which normally arrange so that the wind is blocked by the houses upstream as seen in Fig.1.
This study describes a computational fluid dynamics (CFD) analysis to improve the potential use of natural ventilation in the housing development in Thailand. And to support the careful considerations of natural ventilation strategy during the design process of urban designers, landscape architects and architects who involve in the design process of land lot alignment.

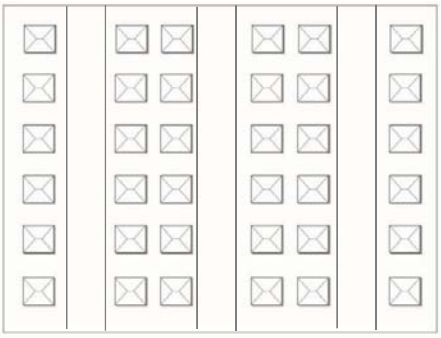

Fig. 1 Grid alignment of land lot of the housing development project.

2. Methodology

There are two steps for the improved potential use of natural ventilation in this study; i) the simulation model of housing development of 2 types of housing setback arrangement are studied, the base case with the linear grid alignment and the design case of the staggered grid alignment. This step offers the result to quantify the higher air velocity to the downstream houses, ii) after the housing setback was adjusted, the wind velocity inlet are re-simulated and measured inside rooms of the tested house to see the improvement of wind velocity.

After the review of the 2 storey house in 100 housing development projects in Thailand with the usage area not exceeding 200 m^2, the reference house is selected based on its room function. The total area of the 2 storey reference house is about 120 m^2 with three bedrooms, one living room, one dining room, two bathrooms and one kitchen. Computational Fluid Dynamic (CFD) simulation program is used to simulate the direction of prevailing wind and wind velocity.

2.1 Climate Analysis

Thailand situated between 6 and 20º N latitudes with a typical tropical climate. The main characteristic of Thailand's climate conditions are high temperature and high humidity. The climatic condition within Bangkok (14º N and 100º E) are used in the simulation as a reference case. Climate Consultant 5.5 software are used to obtain basic data of Bangkok provided by the US Department of Energy (Fig. 2-4). The suggested adaptive comfort using natural ventilation mean outdoor dry-bulb temperature ranges from 26.0°C to 30.8 °C, with a comfort operative temperature between 23.3 °C and 29.9 °C. The relative humidity (RH) data is shown to be between 68% and 75%. The wind velocity ranges from1.9 to 4.2 m/s with the annual mean wind speed at 2 m/s as seen in Fig. 3.

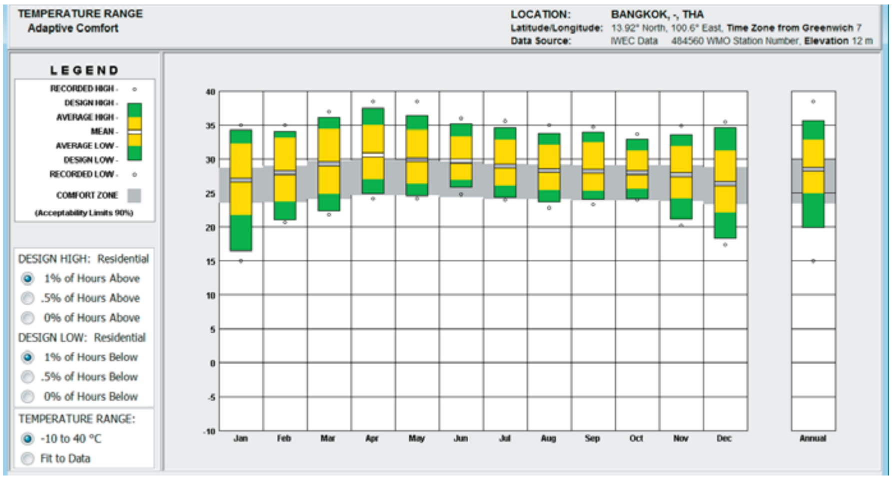

Fig. 2 Temperature range of Bangkok. *Source*: Climate Consultant software.

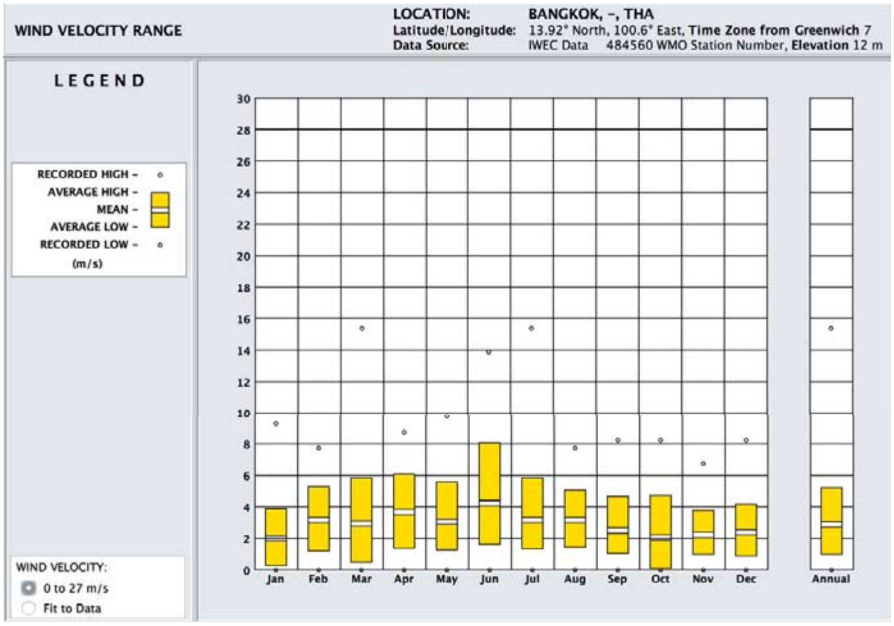

Fig. 3 Wind velocity range of Bangkok. *Source*: Climate Consultant software.

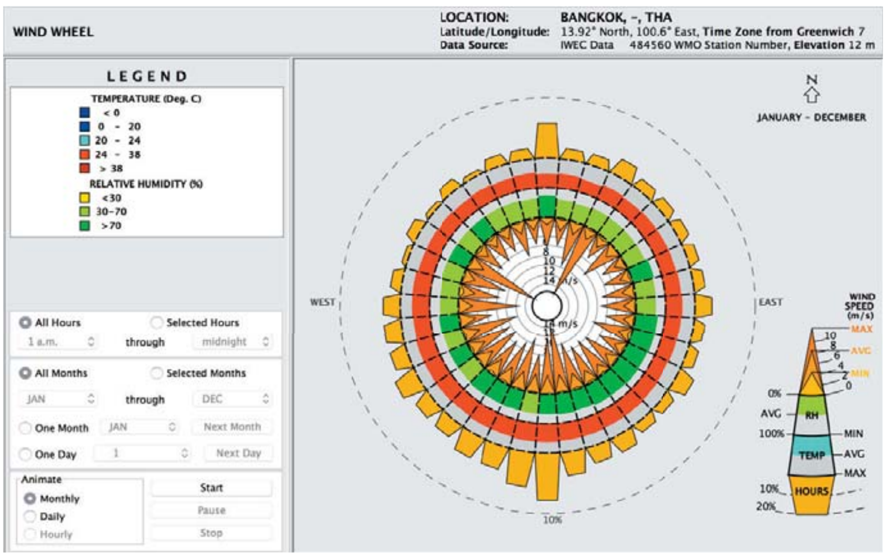

Fig. 4 Wind wheel of Bangkok. *Source*: Climate Consultant software.

The prevailing wind direction is on the South (S) orientation with almost 8% of hours of the year and North (N) orientation, with a little due East (E) with also 7% of hours of the year as seen in Fig. 4. This seems to comfort with most of Thailand's weather with the South-West monsoon during May and September, and the North-East monsoon during October and February [3].

2.2 Thermal Analysis

Some studies have been done regarding the use of natural ventilation in residential sectors [4], [1], [3]. For the similar passive cooling approach, it was also suggested that thermal comfort limit used for Thai can be extended due to the strong air movement with indoor wind velocity about 0.4 m/s or more which can provide a free comfort for 1825 hours per year (about 20% of the time) [1].

3. Results

For the first step, the 2 storey houses in both cases are set as a 7 by 8 m square on the 6x6 grid row. This is to represent the grid alignment normally found in the housing development project. The CFD analysis used the reference minimum wind speed of 1.9 m/s from the South direction as the most critical prevailing wind. The selected house for measurement is on the fifth of the sixth row and the third house from west of the housing grid alignment to represent the worst case of the house downstream.

The study can infer to the North winter wind direction since the site plan would be in the exact opposite direction. The measurement is assumed at the middle of window on the second floor at 5.5 m above ground. In the simulation, the reference house is modelled with aperture while the rest of the houses are solid because the apertures impact on the downstream pressure and wind distribution would be minimum [5].

3.1 Grid Alignment of Site planning

3.1.1 Linear grid alignement

The result shows that for the linear grid alignment, the house upstream blocked the prevailing wind on the house downstream significantly. The wind velocity at the probe value (inlets of the reference house) shows the average wind speed at only 0.18 m/s as seen in Fig. 5.

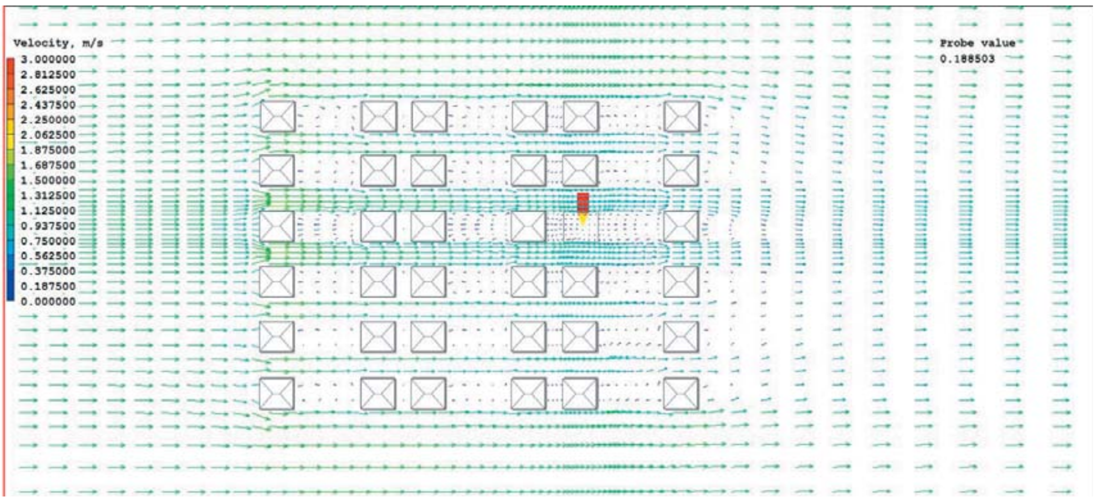

Fig. 5 Linear grid alignment results.

3.1.2 Staggered grid alignment

The staggered grid alignment is applied to the site plan to improve the speed of wind velocity around the house. The wind velocity at the probe value (inlets of the reference house) shows the higher average wind speed at 0.47 m/s as seen in Fig. 6.

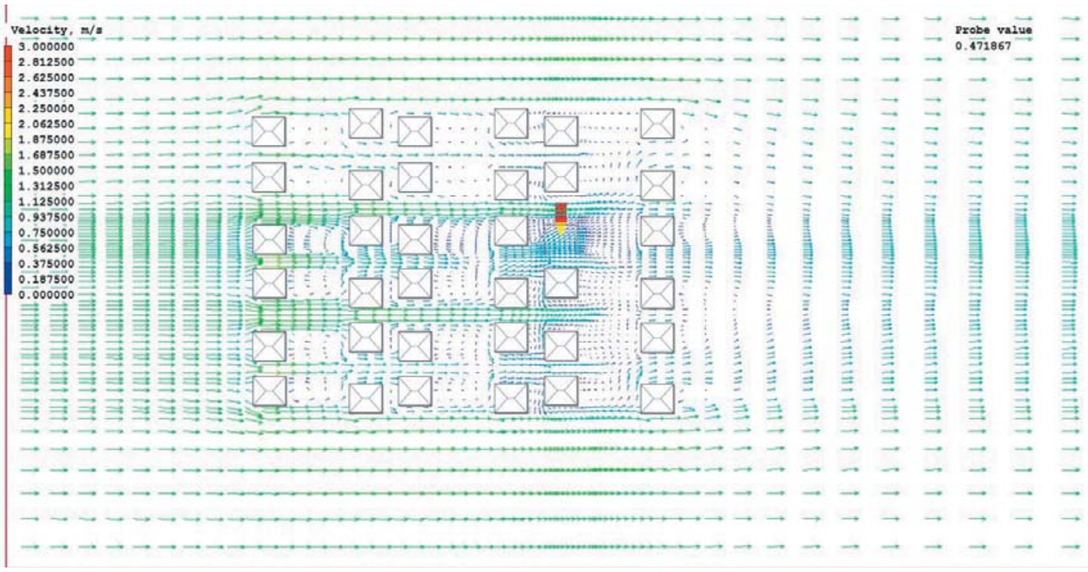

Fig. 6 Staggered grid alignment results.

3.2 Room function adjustment

After the possible wind velocity are acquired from the re-design of the site planning's grid alignment, the space function are reviewed to see if there are more potential to bring higher wind velocity into most spaces with in the house. The CFD model of 2 storey house used in this study is seen in Fig. 7. The probe value is set at 1.2 m above the floor level in each floor.The analysis were done to identified the wind velocity on the base case house and the proposed adjustment of room function are presented. The location of the house is assumed to be at the same position as in the site planning of the staggered grid alignment. The prevailing wind of 0.47 m/s is re-simulated from the staggered grid alignment entering the apertures from the back of the house (opposite of car park area) as seen in Fig. 8-9.

Fig. 7: Base case space function for first floor plan (a) and second floor plan (b). *Source*: Pruksa co.,ltd.

3.2.1 Base case

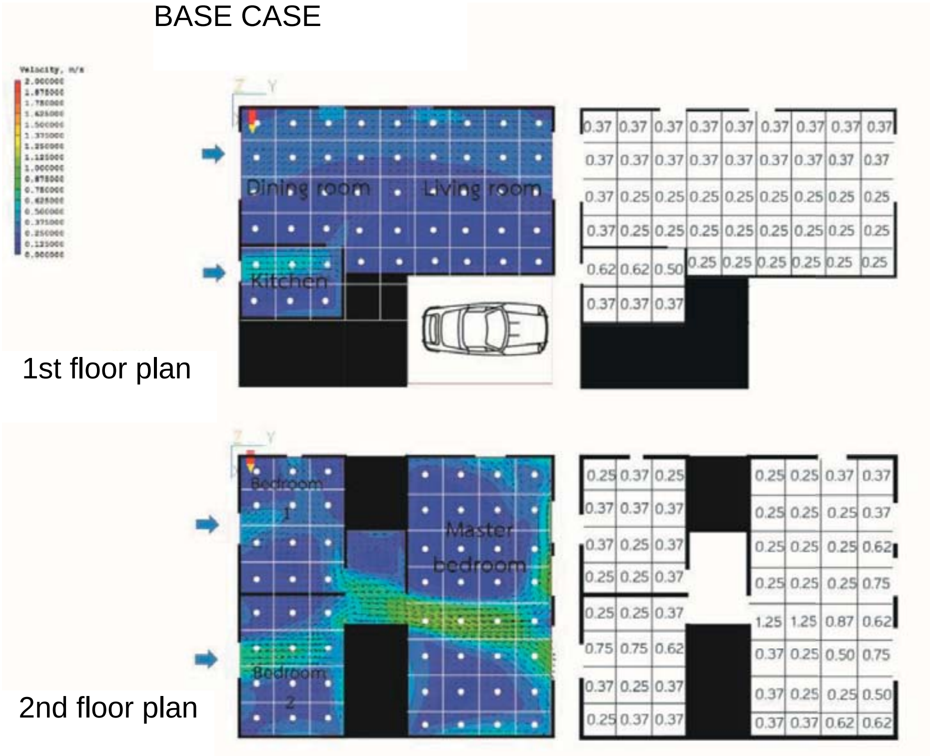

Fig. 8 Base case wind velocity's results.

3.2.2 Adjusted function case

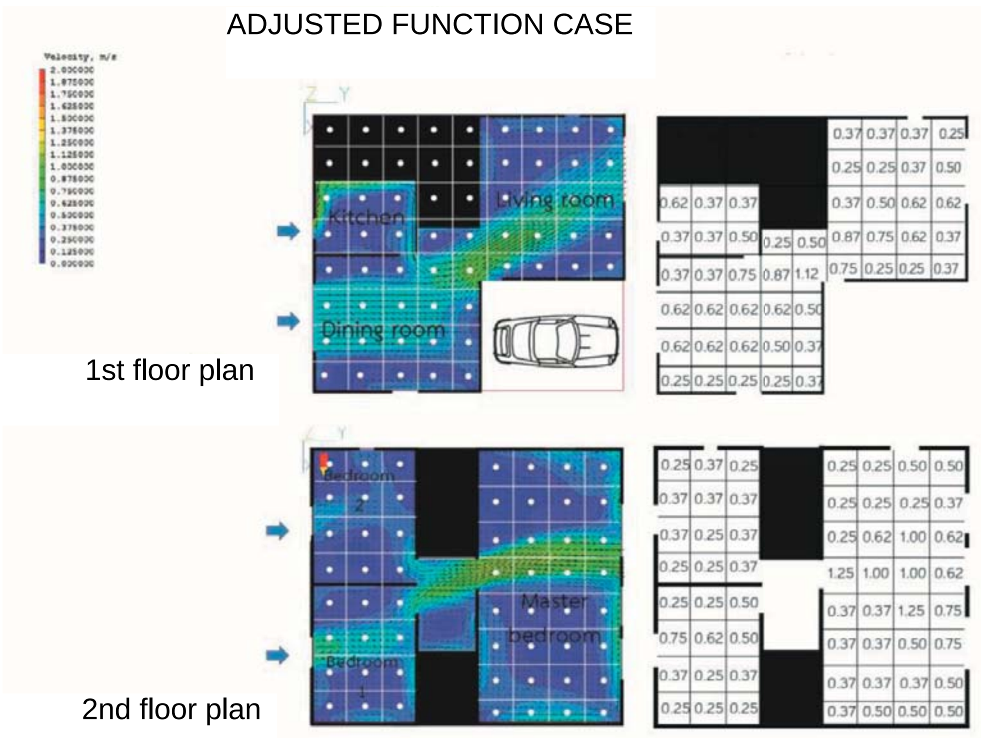

Fig. 9 Adjusted function wind velocity's results.

It was found that for the first floor of the house in the base case, the living room and the dining room are aligned with each other as commonly found in many housing development plan and resulting in average wind velocity at 0.30 and 0.31 m/s. The higher average wind velocity of 0.47 m/s is presented in the kitchen. However, on the proposed adjusted function plan, the living room is flipped with the garage. The living room and the dining room's average wind velocity are increased to 0.45 and 0.53 m/s respectively. The kitchen's average wind velocity is still at the acceptable value at 0.43 m/s which is still higher that the suggested 0.4 m/s wind velocity to provide thermal comfort.

For the second floor of the base case, the master bedroom and two smaller bedrooms when flipped and not flipped show no significant different in the average speed of wind velocity. Still, the adjusted function case shows to have higher wind velocity in the master bedroom.

Table 1: A comparison of wind velocity between Base case and Adjusted function case.

		wind velocity (m/s)	
	Room Function	BASE CASE	ADJUSTED FUNCTION CASE
1st FL.	Living Room	0.30	0.45
	Dining Room	0.31	0.53
	Kitchen	0.48	0.44
2nd FL.	Master Bedroom	0.45	0.54
	Bedroom 1	0.32	0.40
	Bedroom 2	0.41	0.37

4. Discussion

The results discussed in previous section give the insight as to which grid alignment and room function position should be in the housing development project to improve natural ventilation for thermal comfort.

4.1 Grid alignment of land lot

By realigning the land lot into the staggered grid alignment, the wind velocity at the reference house improve from 0.18 m/s to 0.47 m/s. The results also show that when located on the same size of land lot, the different alignment can gives the house a higher wind velocity by 61.7% and suggesting that the staggered grid alignment of land lot is more appropriate for natural ventilation. And this result is conform with another study that to align the building correctly since the design of site planning process especially for Passive cooling design shows the significant improvement of thermal comfort and reduce air-conditioning energy usage [6].

4.2 Room Function adjustment

When considered the wind velocity within the room of the 2 storey house, the simulation results show that the average wind velocity in Living room and Dining room are reduced to 0.3 m/s due to toilet, kitchen, and stair blocked the wind. To encourage more natural ventilation in those spaces, toilet, kitchen and stair were flipped into another side of the house. The air velocity in living and dining rooms were improved significantly by 33% and 42%, respectively and increase to more than 0.4 m/s which prove to be thermally comfort for Thai people.

5. Conclusion

There are some conclusions that can de drawn from this study. First, a key consideration is the house setback in housing development's grid alignment can cause significant improvement to the house on the downstream both in and around the house. The staggered grid alignment proved to be enhancing the wind direction and velocity significantly. As for further investigation with in the house, it showed that careful consideration of placing room function within the house can increase wind velocity resulting in possible higher thermal comfort for the occupants. For example, the room functions such as Living room and Dining room when placing correctly can increase wind velocity without disturbing the functioning of the house.

In conclusion, this paper has demonstrated that by simply re-aligning the grid of land lot and rearrange the function of the house can improved the potential use of natural ventilation to provide free passive cooling that can lower the air-conditioning energy usage and provide enough thermal comfort for the housing development project in tropical weather such as Thailand. For future research the combing strategy between natural and mechanical ventilation such as hybrid ventilation (HV) or Mixed-mode ventilation (MV) should be investigated. Also the energy savings from this approach is needed to be realised in order to provide more insights into how to use various ventilation strategies in a hot-humid climate such as Thailand.

6. Acknowledgements

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7. References

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A holistic Methodology for District Retrofitting projects management through an Integrated Decision Support Tool

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Summary

Keywords: Urban District Retrofitting, Sustainability, Energy, Decision-Support, Software Tool

1. Introduction

The European building sector is responsible for 40% of overall energy consumption sector and over 50% of all materials extracted from earth are transformed into construction materials and products [1]. With more than 70% of the building stock built before the first energy crisis (1970's), energy retrofitting of buildings is envisaged as the most promising strategy to reach the EU's "40-27-27" targets. However, the results of retrofitting interventions on building scale have shown that the effectivness of building retrofitting can be increased significantly through considering each building as a part of a global energy system in a district. This follows the approach of considering all buildings loacted in the same district as an entity. In this case the application of retrofitting measures is not limited to single buildings only but can be applied on district level through exploiting synergies and interactions between buildings and their surrounding infrastructure and environment. While planning retrofitting concepts for single buildings is a challening task the complexity and work intensity for planners on district scale increases significantly. While acting on district scale planners have to consider how implemented measures on single buildings may affect the implementation of measures for other buildings loacted in the same district. Retrofitting measures on single buildings even may have negative impacts for other buildings or the whole district sustainability performance if they are not planned proactively. For instance the feasibility of establishing heat networks between buildings is strongly depending on the available heat demand density in an area. Thus, planners in district retrofitting projects have to assess if retrofitting measures on single buildings like improving the building envelop are more sustainable than connecting the buildings to a renewable driven heat network. In order to find the optimum solution in terms of sustainability for a whole district planners have to consider several criteria like the total impacts on the environment, the life cycle costs, the return of investement as well as social impacts of the planned measures. Moreover, in order to gather all the needed informaton for a sensible planning process and to achieve the most effective results planners have to cooperate with all involved stakeholders in a well-coordinated and structured way. Among others, representants of the municipalities, building owners, tenants, financing bodies and energy supplying companies have to be involved in all phases of the planning and implementation process. This presents a major challenge to planners of district retrofitting projects and can only be solved following a well structured and thoughtful methodology which guides the planners and all involved stakeholders through the different phases of the project. To facilitate the planning on district scale and to improve the effectiveness of the planning and implementation process of energy retrofitting measures the use of an advanced and integrated planning and decision-support tool (IDST) is indispensable.

2. Methodology

2.1 Objective and user requirements of the IDST

In order to satisfy the need of holistic planning tools on district level need FASUDIR provides an Integrated Decision Support Tool (IDST) based on an innovative methodology, supported by a software tool. The IDST evaluates retrofitting needs of a set of buildings that share a common urban area and guides the decision makers in finding the optimum energy retrofitting strategy to increase the sustainability of the whole district. Understanding user requirements and their business objectives in undertaking potential district retrofitting projects is crucial to designing an effective decision support tool. With this in mind, at the beginning of the Methodology development an in-depth survey of a wide range of stakeholders was undertaken. The survey took place in Italy, Germany, Hungary, Spain and UK, being coordinated from London Business School and executed by the country-specific partners involved in the task. The stakeholders identified ranged from federal government planners through architects, technical advisers, local planners, energy suppliers and ESCOs to owners and social housing managers, covering district projects that range from three or four buildings to many thousands [3]. Potential users evidently value an approach that is easy to understand and helps to guide users' preferred solutions, though various constraints, to a well-structured, multi-criteria trade-off analysis. The results of the survey showed that FASUDIR will be applicable for different user styles of engagement. Mainly engaged will be technical staff and planners. However, the framework of the IDST allows all identified stakeholders to be involved in the different stages of district retrofitting projects by different functions of the IDST and different phases of the methodology. Through the high flexibility, the broad approach and the use of an plain language User Interface it is also possible for non-expert users in the fields of energy like facility managers, building owners or citizens to use the IDST for the creation of own retrofitting variants of their buildings and to visualize results. As the FASUDIR methodlogy takes advantage of the Pareto Principle sufficient accurate results can be obtained with acceptable effort and in short time.

2.2 The FASUDIR Decision-Support Methodology

The execution of district retrofitting projects is a very multifaceted task for planners and all involved stakeholders. Compared to building level projects the complexity on district scale grows exponentially while the data availability declines. So, planners need a sophisticated decision-support methodology to handle the complexity in an appropriate way. Therefore the FASUDIR Methodology divides district retrofitting projects into four main steps which planners can work off in a structured work process. The four steps are defined as followed:

- Preparation Phase

- Diagnosis Phase
- Decision-Making Phase
- Implementation Phase

Preparation Phase
The preparation phase is the beginning of each district retrofitting concept. In this phase all necessary data to create a citymodel is collected from several sources (GIS, CityGML, on-site inspection, owner and occupant surveys, etc.). The FASUDIR IDST supports planners in collecting the data by involving all stakeholders that may be able to provide needed data via an e-collaboration platform. Hence, planners are able to request data from different data providers in a structured data collection process. Stakeholders are able to share digital data or to respond on the requests of the planners. E.g. owners, ESCOS or representants of municipalities are able to upload geodata files on the platform which can be utilised by the planners. Owners and tenants can fill an online-survey which asks them several for the building characterisation necessary data that cannot be obtained from default data or on-site inspection from the outside of the buildings (heating system, average number of occupants, measured energy data, etc.) [4]. Planners use the e-collaboration platform as a supporting tool in the preparation phase. It supports them in accelerating the data collection by an improved information flow between planners and other stakeholders (see Figure 1).

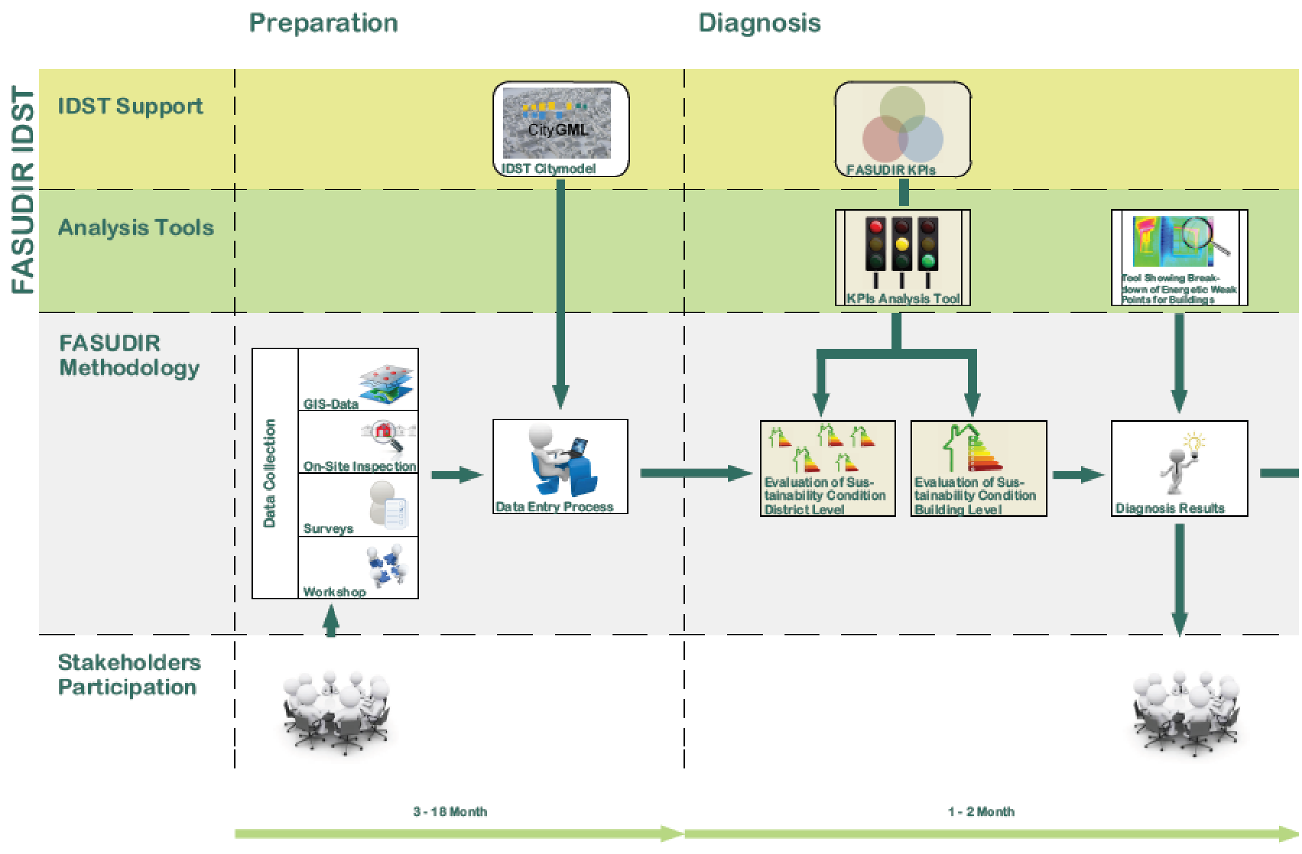
Diagnosis Phase
The second phase in the FASUDIR Methodology is the diagnosis phase which allows an evaluation of the current state and the definition of useful targets for a district retrofitting project.
After the data entry process has been finished all necessary data to run a first simulation for assessing the current state of the whole district and all buildings in the district is available in the IDST Citymodel. The current state is analyzed according to its global sustainability by the use of Key Performance Indicators (KPIs) which have been defined in the FASUDIR Methdodlogy on building and district level [5]. To assess the current sustainability state of the district and each building the following in Table 2 listed KPIs are used:

Table 1: Key Performance Indicators of the FASUDIR Methodology with scale of application

Category	Indicator	Scale of Application
1. Ecologic Category	Total Primary Energy Demand	Multiscale
	Energy Demand in Operation (delivered)	Multiscale
	Energy Embodied	Multiscale
	Share of Renewable Energy on Site	Multiscale
	Global Warming Potential	Multiscale
	Acidification Potential	Multiscale
	Ozone Depletion Potential	Multiscale
	Eutrophication Potential	Multiscale
	Photochemical Ozone Creation Potential	Multiscale
	Abiotic Depletion Potential Elements	Multiscale
	Soil Sealing	District Scale
	Intensity of Water Treatment	District Scale
2. Social Category	Indoor Air Quality	Building Scale
	Thermal Comfort	Building Scale

	Visual Comfort	Building Scale
	Motor Transport Infrastructure	District Scale
	Public Transport Infrastructure	District Scale
	Accessibility to Infrasturcture	District Scale
	Urban Microclimate / Heat Island Effect	District Scale
	Gentrification Risk	District Scale
3. Economic Category	Life Cycle Costs (LCC)	Multiscale
	Return on Investment / Payback Period	Multiscale
	Change in value of property	Building Scale

Thus, all KPIs are calculated by the IDST based on the simulation results. Additionally, each KPI is compared to a defined benchmark from the methdodlogy which allows evaluating the KPI result compared to a sensible average value. This allows the user of the IDST to identify the strengths and weaknesses of the district in terms of sustainability. A low KPI value in this case means that the sustainability issues which the KPI addresses must be improved. To support the visualization of the KPI results to the user the IDST provides a special KPI Analysis Tool which is used every time the user wants to check KPI results. The KPI analysis tool also is used to assess the created energy variants in the decision-making phase. Moreover, to enable a detailed evaluation of the district's and building's results the user has the possibility to display selected raw data of the simulation results (see Figure 1). These for example are the direct simulation outputs which are stored in the building and district result records of the Citymodel. The user therefore is able to access and display all data that is stored in the city model databases on a map. Thus, the user also has the possibility to export the data generated in the current state evaluation for further purposes beyond the FASUDIR IDST.



Decision-Making Phase

The decision-making phase is the third phase in the FASUDIR methdodlogy (see Figure 2). The decision-making phase enables the decision makers to define the district retrofitting project through the selection of the most sustainable retrofitting solution in terms. To achieve these objectives a structured methodological approach to fulfill all the needs has been developed. At the beginning the planners are able to create scenarios representing a district retrofitting project which are defined by setting measurable targets and objectives for the improvement of the KPIs. The target definition is based on the current state evaluation of the KPIs and is also linked to the e-collboratuion platform. All involved stakeholders therefore can participate in the target definition process by giving votes on their targets and priorities.

Creation of Retrofitting Variants in the IDST

After the targets for project have been defined the planners are able to create different retrofitting variants. Therefore it is possible to select different retrofitting interventions on building and district level from a pre-defined selection list. In order to apply only useful and technically feasible retrofitting measures on buildings it is essential to know which retrofitting measures work well or may not work for the buildings or whole groups of buildings. Even though planners of retrofitting variants may have a good knowledge about the feasibility of different retrofitting measures the Methodology supports and guides them in the selection process. Therefore, the IDST provides a comprehensive tool box with several useful analysis functions that help planners in evaluating the practicability of different solutions. The main challenge for planners in creating energy retrofitting variants for urban districts is to estimate the impacts of different solutions onto the buildings and the energy supplying infrastructure in the district. Those synergies and interactions between buildings and the district were analysed deeply in the methdodlogy development and can be assessed using the IDST. The provided retrofitting interventions in the IDST repository of technologies are classified according the following categories:

1. Reduction of energy consumption (consumer-driven)
2. Increasing the efficiency of the energy supply
3. Inclusion of renewable energy production

All categories contain several traditional off-the-shelf retrofitting measures as well as new innovative ones at building and district level. On building level it is possible to apply several envelop improvement measures (adding insulation, replacing windows, etc.), replace HVAC systems, increase the efficiency of electrical appliances and to include renewable energy sources (photovoltaics, solar thermal systems, CHP, biomass, etc.). On district scale, users can apply improvement measures in the fields of street lighting (LEDs), heat and cooling networks as well as renewable district energy systems (wind turbines, photovoltaic farms) and further. Moreover planners have the possibility to assess the improvement of non-energy related measures in a scenario like increasing the green spaces in the district or improving the accessibility to public transport stations. The KPIs are simulated for each variant representing the different applied retrofitting interventions.

Intervention Filter Logic based on constraints and restrictions

Although a variety of different retrofitting technologies is theoretically available for buildings and districts in the IDST the applicability of each technology in real life projects is often limited. Because of the fact that each district and even each building in a district is an individual case a lot of available retrofitting technologies cannot be implemented due to constraints and restrictions in different fields. To support the planners in considering all potential restrictions on interventions the IDST provides thoughtful filter logic. The filter logic is able to consider the different constraints and restrictions for the application of retrofitting interventions on each single building and the infrastructure by using the simulaton outputs from the current state assessment.
For example if a building in the district is under cultural heritage protection it can be set as a planning constraint in the preparation phase by the user. In this case external wall insulations will not be selectable for the user in the variant creation due to the filter logic. Moreover, the IDST takes advantage of simulation results generated through the current state assessment. For example if the suitability of roof or façade areas for solar energy on a building is not given this is automatically set as a constraint in the filter logic by the IDST. Hence, the IDST in this case is able to exclude solar based retrofitting technologies (photovoltaics, solar thermal systems) which exceed the available roof or façade area of a building by the use of the filter logic.

IDST Analysis Tools and Functions

Following special analysis tools and functions to support the variant creation are provided within the IDST:

1. Analysis tool assessing the energetic weak points of buildings
In order to prioritize different retrofitting measures to reduce the energy consumption and to increase the energy efficiency of a building it is necessary to know which represent from an energy view the weakest points of a building. This means the FASUDIR IDST supports the users in identifying the building components or systems which cause the highest energy losses and therefore, have with high probability the greatest energy saving potential. Hence, with the Energetic Weak Points Tool the FASUDIR user is be able to plan the retrofitting measures in a way that allows exploiting the most effective energy savings.

2. Tool assessing the feasibility of heat networks
The FASUDIR IDST provides a function that allows planners to assess the correlation between different retrofitting measures and the capability of heat networks for groups or the whole district. The function in the IDST calculates for user defined building groups or areas of the district a heat demand density map and visualizes it in 2D and 3D maps. By setting user defined thresholds the function shows the user the areas of a district or a city in which the construction of a heat network can be feasible.

3. Analysis tool for the assessment synergies and interactions between buildings
The fucntions shows the user the time-based load curves of the electricity consumption and the electricity generation (CHP, PV, Wind) of a group of buildings or the whole neighbourhood. Moreover it allows the user to assess how much electricity surplus is generated at which times to plan smart grids and electricity storages (charge e-vehicles, intelligent appliances).
4. Analysis Tool Assessing Solar potentials of Surface areas on Buildings and free spaces

The function shows the user for each building in the neighbourhood the suitability of roof and façade areas for photovoltaics or solar thermal systems (solar potential).

5. E-Collaboration Platform
The e-collaboration platform in the FASUDIR IDST is the central hub between the planners of a district retrofitting concept and all involved stakeholders and guests. The e-collaboration platform provides the framework to support the stakeholder involvement in each phase of the FASUDIR methodology. The platform is accessible via the main created project website of a district retrofitting project. Therefore, the e-collaboration platform enables the following features for the users:

- Online-Discussion-Forum (Citizen Participation, idea collection, etc.)
- Online Retrofitting Questionnaire (Owners, Tenants)
- Online cloud-based data storage for file exchange
- Front-page for announcements (News, Dates for Physical Workshops)

Variant Assessment

After planners have created variants the IDST is able to compare the variant to identify the most suitable one according to the set priorities of the decision-makers. In the assessment step of the methodology the users is supported by a decision-support tool. In this function all gathered information, conducted upstream analysis and generated data outputs in the different steps of the variant creation are finally stored in a database. The main input of the variants in the decision-support function is in the form of the KPIs results. The KPI results afterwards are used as core criteria in a value assessment to rank the different retrofitting variants according to the preferences of different stakeholders and decision-makers. Thus, planners of retrofitting concepts have a powerful and logic feature to support the complex decision-making process in energy retrofitting projects for urban districts. In order to be able to conduct a value assessment based on a Multi-Criteria-Decision-Analysis (MCDA) approach the valid variants are ranked according to the preferences and priorities of the decision-makers. For all created retrofitting variants the different KPIs are simulated by the IDST. To set the priorities the IDST provides a Decision Support Tool which allows the FASUDIR Users to enter their priorities from a list through a plain language entry mask. The plain langaue entry mask translates priorities in a weighting system. Hence, the weights for the different KPIs in the value assessment are adjusted automatically.

Implementation Phase

The implementation phase is the last phase of a district retrofitting proiject in the FASUDIR Methdodlogy (see Figure 2). In the implementation phase the best ranked variant of the district retrofitting concept has to be practically implemented. Therefore it is the longest phase in a district retrofitting project and can last from 2 years up to 20 years or even longer depending on the motivation of the stakeholders and owners. The focus of the FASUDIR Methodology therefore is not the complex work of planning the detailed retrofitting construction process. This task should be done by a retrofitting manager who has the final responsibility for the coordination of the retrofitting construction process. However, FASUDIR supports the complex work of the retrofitting manager by the IDST and the related supporting tools. To achieve this, the IDST provids an update and monitoring function which allows updating and monitoring the current state of the district according to the already implemented retrofitting measures by the owners. The updated current state can be compared to the targets that have been defined in the scenario. Thus, the retrofitting manager and the represents of the municipality have the possibility to check the current progress during the whole implementation phase. This is very important in order to control the retrofitting progress and to identify obstructions which have negative impacts of the retrofitting work. Based on the results the retrofitting manager is able to develop suggestions for improvements (e.g new grants, change of the variants) and to recommend them to the stakeholders. Moreover, the achieved successes in the retrofitting project can be shown and demonstrated to politicians, stakeholders and citizens by using the IDST. Furthermore, the IDST supports the retrofitting manager in improving the communication flows between the stakeholders in the implementation phase through the e-collaboration platform. Hence, the retrofitting manager is able to contact all stakeholders in an optimized way via the internet. This facilitates the mediation between different stakeholders which is very important in the implementation process of district solutions.

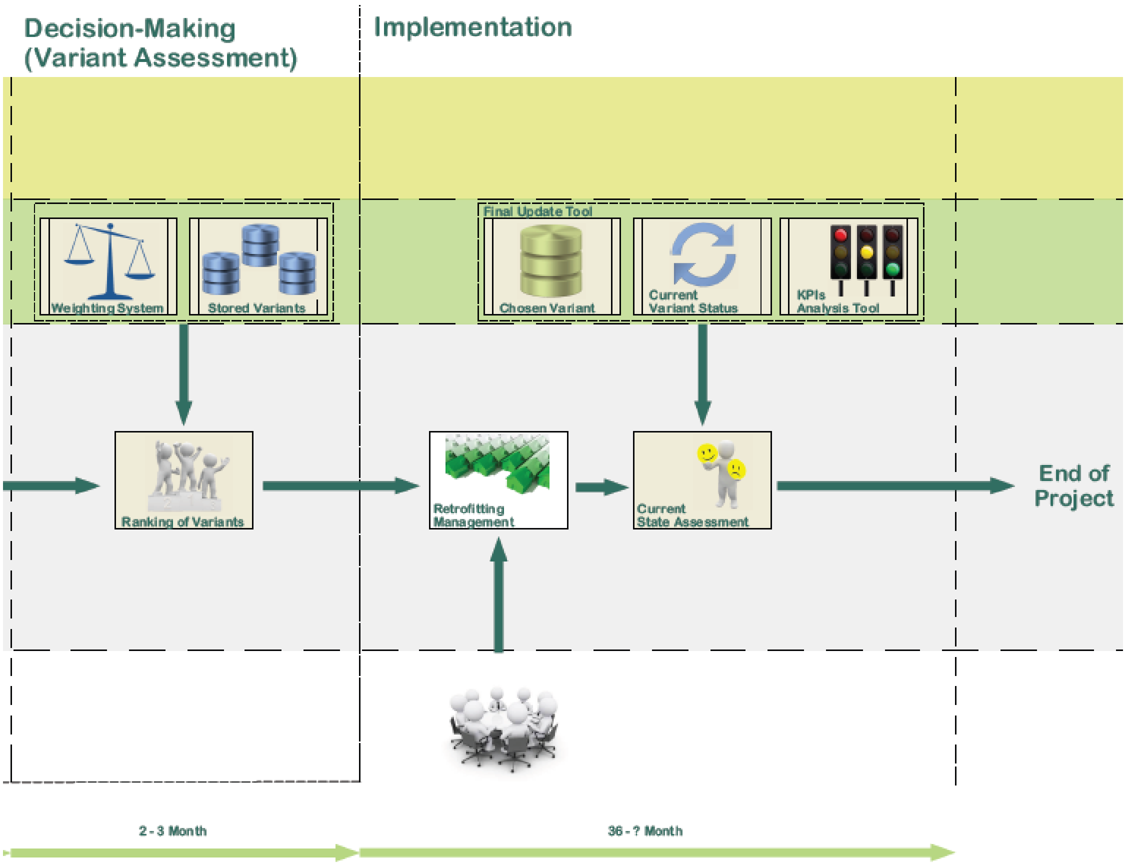


Fig. 2 Overview Chart on the Decision-Making and Implementation Phase in the FASUDIR methodology

3. Results

3.1 Usability of the FASUDIR Approach in Europe

The proper functions of the IDST and the connected Methdodlogy have been validated on three case studies. The results show that the high flexibility and usability of the FASUDIR approach facilitates a broad application in Europe and beyond. The data collection phase for the creation of the Citymodels in the case study sites has been identified as the main bottleneck of the FASUDIR approach. Especially the quality and availability of GIS data, which is needed as basic input for the FASDUIR Citymodel, is not for in all cases available. Furthermore if the data is available the quality in many cases is not sufficient and an intensive data reprocessing is necessary. Another limiting factor is the high price for buying the underlying GIS data from land surveying offices. However, as the distribution of high quality GIS data in Europe will improve in the near future the usability of the FASUDIR approach will become even easier and cheaper. The exploitation of the FASUDIR Methodology and IDST Tool are in progress now. Several cities, urban planners and professionals have tested the first version of the IDST in special local project commitee meetings. The feedback of these meetings has shown a strong demand of advanced decision-support tools for district retrofitting in Europe.

3.2 Comparison of IDST results with real measured data on the case study sites

After finalizing the IDST prototype the FASUDIR methdodlogy and IDST have been validated on three real case study sites:

- Cultural heritage districts: historic city quarter of Santiago de Compostela (Spain), founded on the XIII century
- Communist era district from the XX century: Residential district with public buildings in Budapest (Hungary)
- Residential districts built up on the 1970's decade of the 20th century (Germany): Heinricht-Lübke-Siedlung (Frankfurt)

The validation of the results provided by the IDST was done against real data that were achieved by the real retrofitting project. The real application on case studies of the IDST allowed the consortium to start a refinement phase needed to finalize the tool. The results showed that the accuracy of the IDST is sufficiently precise for the purpose of decision-making on district level. Indeed, the simulated global energy demand of the case study districts remained close to the respective real measured values. For few single buildings significant deviations to the real values were identified caused by poor input data availability. In the case studies also a balancing effect for the results was identified, which averaged out deviations to the real measured values through the high number of buildings.

3.3 Sensitivity Analysis

In order to assess the effects of poor data quality on the simulation results and the decisions-making a comprehensive sensitivity analysis has been carried out. The reults have shown that the accuracy. The main sources of uncertainties in the FASUDIR Project related to the risk associated with KPIs analysis can depend on such issues as the quality of the available and used data and the good scoping, pricing assumption and methods of calculations. For the analysis of KPIs the input of uncertainty parameters and stochastic methods, such as Monte Carlo simulations have been employed. In order to reduce the impacts of uncertainties for the decsions-making measures have been be taken into account in the IDST development. For example users are warned by the IDST if KPI results may be affected by a high risk of uncertainty (e.g. if input data quality was poor).

4. Discussion

In fact it is very difficult to assess the uncertainties that may occur in district retrofitting concepts. However, the goal of district retrofitting concepts and the district approach in general is not to provide as detailed results and calculations as possible but to help planners and stakeholders to find the right direction for the whole district. As the data collection in a district is not as detailed as for building retrofitting concepts the uncertainties are higher on district level. However, the time effort for the data collection can be reduced by up to 80 % compared to a detailed data collection. Therefore the Pareto principlestates those, for many events, roughly 80% of the effects come from 20% of the causes. If the Pareto Principle is applied to the data collection process for buildings and districts 80 % of the accuracy can be reached with 20 % of the time and cost effort. If the planners need to have 100 % accuracy the time effort for the data collection will be increased by 80 %. FASUDIR therefore is created as a tool for high level insights and therefore takes advantage of the Pareto Principle.

5. Conclusion

Besides the planning of concepts, the practical implementation of the measures cannot be done by software tools as a deep interaction and communication between all involved stakeholders is necessary. Hence, the planning and practical implementation of district retrofitting projects is a task that is due to its high complexity still strongly dependent on the human intelligence of professionals and experts. However, the professional planners can take advantage of structured approaches and supporting software tools to make their work more efficient. Against this background the Decision-Support Methodology must be regarded as a stand-alone approach which is not directly coupled to tools or software. This means, that the FASUDIR Decision-Support Methodology in general is applicable without the use of the FASUDIR IDST. However, to follow all steps included in the different phases may need a lot of time and partially be not effective without using appropriate support by the IDST. Vice versa the IDST also cannot be seen as a stand-alone tool. Using the IDST in an appropriate way needs to follow the structured Decision-Support Methodology in order to achieve meaningful and resilient results. The development of the FASUDIR Decision-Support Methodology and the IDST will significantly improve the currently used methods of operating in district retrofitting projects and facilitate keeping the EU's "40-27-27" targets for the building sector.

6. Acknowledgements

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Application of a parametric LCA tool in students' design projects

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Summary

In winter semester 2014/15 students at the Bauhaus University of Weimar and students of the University of Mersin employed a self-developed parametric tool for life cycle assessment (LCA) during design. Throughout the semester the students presented the LCA results of their current design every week. The final results showed that the students were able to save an average of 16% of Global Warming Potential (GWP), compared to a default variant. In comparison to a reference group who did not apply this tool they achieved designs with only half the GWP. The project demonstrates that, if they have the right tools at their disposal, even non-experts can apply LCA during the design phase without much additional effort. Furthermore, the GWP reduction clearly proves the application to be worthwhile.

Keywords: Student design project, architecture, LCA, parametric model, building simulation

1. Introduction

Life Cycle Assessment (LCA) is becoming more and more important for building evaluation. For some building certifications, e.g. the German DGNB [1] and BNB [2], it is a mandatory part of the certificate. Sustainability criteria also become more important for architectural competitions [3]. In recent competitions the participants have to describe their approach to reducing the environmental impact, including the saving of energy and greenhouse gas emissions.
In general, decisions made in the early phases of the design have significant consequences, since they define the general conditions for the subsequent planning process [4]. In that way they have the biggest impact on energy demand [5]. Thus, an optimization of the design with regard to a low environmental impact can best be achieved in early design stages.

The quantitative evaluation of the environmental impact through LCA requires, amongst other things, a calculation of the energy demand and a bill of quantities. However, the most fundamental decisions, such as building form, orientation and window arrangement, the architects often make in the early design stages, with little or no involvement of simulation software [6]. In Germany, an energy demand calculation is mandatory for a building application. At that time most design decisions have already been made and changes to the design usually require a high effort.

In current practice, the energy demand calculation is usually carried out by an energy consultant. If LCA is involved, the person in charge receives a bill of quantities from the architect and can then feed the LCA tool with all the information, including the results from the energy demand calculation. Overviews on current available building LCA tools can be found in [7], [8]. Most LCA tools require a tabular input of the information, e.g. eLCA [9], SBS online tool [10] or Legep [11]. Recently, different approaches to combine Building Information Models (BIM) and LCA have been developed, which automatically calculate a bill of quantity [12], [13], [14]. In theory, the embodied impact can easily be calculated with those approaches. In practice, the challenge lies in the high complexity the BIM reaches. For both approaches - manual input and BIM - the effort involved with inputting of all necessary information hinders the application in early design stages. Furthermore, once the LCA has been carried out, the results can hardly be used to improve the building, first, because the planning process usually is too short, and second, because the high effort of input impedes the comparison of design variants. Hence, LCA is not applicable for optimisation [15].

In order to allow an architect to analyse the environmental impact of his building while designing it, two major developments are necessary:

1. Simplified tools that are adapted to the architect's need have to be developed. According to Baitz et al. [16], LCA results should rather be produced in time and provide 80% solutions than provide 100% solutions which come too late to have any effects on reality.
2. Architects need to acquire a certain degree of expertise in building physics and LCA to be able to interpret the obtained results. Ideally, this know-how should be taught at the beginning of the architectural education at the universities.

This paper responds to both points. In order to test a novel tool for parametric LCA in the early design stages and to teach the basis of the methodology, we integrated its application in a student design project. A group of nine students used the tool during the design process. This paper describes the outcome and compares the LCA results to a reference group of 17 students who did not apply it.

Experience from two earlier sustainability-related design projects was used for supervising the students' work. The first project, focussed on energy performance, motivated the students to produce very creative approaches, such as using a nearby river for hydropower or integrating a pumped storage hydro power plant into their tower design [17]. The second project introduced LCA into the design process and the students were provided with a simple spreadsheet tool [18]. The manual input of areas got the students to only analyse their final design. As a result, the variants were not analysed during the design process and the optimization was not carried out, which shows the demand for design-integrated LCA tools.

2. Methodology

2.1 Design task

The design task of this project consisted in developing a use scenario, choosing one of three possible sites in the historic city of Tarsus, in the south of Turkey, and finally designing the building. The results were very different building types with differing intended uses, which ranged from cafés and restaurants to exhibition sites and hotels.

The students were asked to analyse the life-cycle environmental impact of their design every week, from the first sketches at the beginning of the semester to the final design. Any decision, from the urban setting to the size of the windows, should be made on the basis of design variants and the corresponding environmental impact. The idea was not to hinder solutions with a higher environmental impact, but to improve the understanding of the relation between design and environmental impact. At the end of the semester the students handed in optimized versions of their design proposals and explained their decisions based on the LCA results.

2.2 Tool

The tool was developed for “Grasshopper3D” (GH) [19], a parametric plug-in for the CAD software “Rhinoceros” (RH) [20]. The tool was applied with a view to optimise the refurbishment of a single family house in Germany [21], [22]. The method is based on parametrisation of all influencing factors, such as geometry, material, service life, etc. The core of the method is an integrated parametric LCA model.

The workflow consists of three main steps: First, the input of geometry, materials and surrounding conditions, second, the simultaneous calculation of operational (I_O) and embodied environmental impact (I_E), which, taken together, add up to the life-cycle impact (I_{LC}), and finally, the visualisation of the results (see Fig. 1). On the basis of this feedback the architect can make informed decisions on changes to the design. Since the surrounding conditions, such as site and user profile, are usually fixed, changes can be made in two parameters: geometry and material. The architect is able to improve his design stepwise towards environmental friendliness.

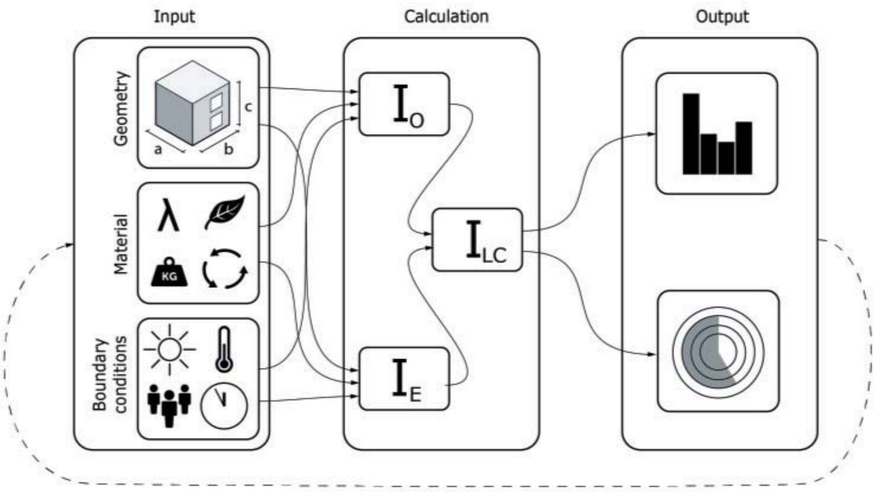

Fig. 1: Workflow of parametric LCA tool in three steps

2.2.1 Input

The input of the geometry is done in RH. All of the geometry is drawn in the form of 2D surfaces. The thickness of each component is input in the material editor. The individual components are drawn on predefined colour coded layers (see Fig. 2). The material is defined in GH. Each component is divided into four functional layers, such as exterior cladding, insulation, primary construction and interior cladding. The material can be selected from a drop-down menu, the thickness is input by means of a so-called number slider (see Fig. 3). All the other surrounding conditions are predefined and cannot be changed by the students.

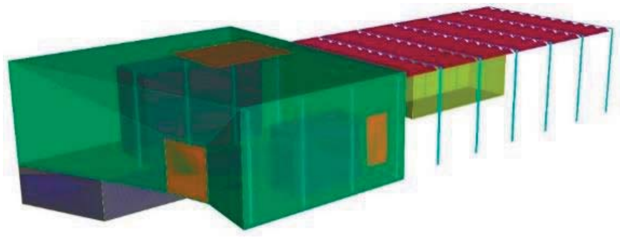

Fig. 2: Geometry model in RH

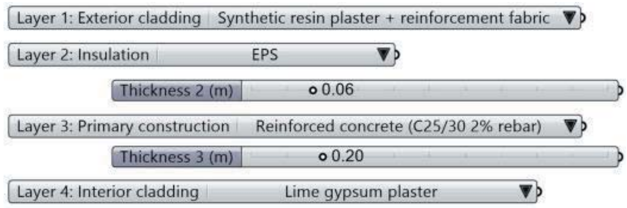

Fig. 3: Parametric material definition in GH

2.2.2 Calculation

For the calculation of the operational impact (I_O), first of all, the energy demand has to be known. In this case we distinguish between energy demand influenced by the building design, such as heating and cooling demand, and energy demand that is mainly influenced by the user, such as electricity for appliances or lighting. The heating and cooling demand is simulated by means of EnergyPlus V8.1 (EP) [23]. The geometry designed in RH is automatically transferred to GH and integrated into a thermal model. To link EP to GH, a plug-in called ArchSim [24] is employed. Then the results for the heating and cooling demand are multiplied by impact factors for the respective energy carrier to give out the total I_O. The impact factors are taken from the German database "ökobau.dat" [25] and imported into GH.

The embodied impact (I_E) is calculated by multiplying the masses of the building components, taken in the bill of quantities, by the individual impact factors of the respective material. These impact factors are also taken from "ökobau.dat" and combined with physical data, such as conductivity or heating capacity, which are needed for the building simulation. This data is imported into GH, together with data on the reference service life of each material, which is provided by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) [26]. If the reference service life of a material is shorter than the reference service period of the building, the necessary amount of replacements is taken into account automatically. I_O and I_E are then added to find out the life-cycle impact I_{LC}.

2.2.3 Visualisation of the results

To facilitate the presentation of the results, only two common indicators – non-renewable primary energy (PENRT) and global warming potential (GWP) – are employed. They are shown in different diagrams (see Fig. 4). A bar graph displays the I_E values of both indicators for the main building components, namely façade, partitions (internal walls), ceilings, roofs, exterior floors and windows (including doors). This kind of presentation enables the designer to see where most of the impact results from and thereby where optimization potential lies. Similarly, the I_O is displayed separately for heating and cooling demand. The indicators refer to area and year (IND/m²a). Two pie charts for both indicators show the I_{LC} in each category. So the overall share of each component/energy demand within the whole life cycle can quickly be seen. Additionally, the yearly I_{LC} for the whole building is output as a numeric value.

Two functional units are used in this case: the whole building and one square meter of conditioned space per year (1 m²a). Apart from the conditioning of the room to a temperature between 20 and 26 °C, no functional requirements have been defined. The results per area serve to compare the different designs with each other, but for the designer the result per building is more relevant, because he tries to fit the respective function to the least I_{LC}. Buildings with more floor area tend to have lower results per area. This might encourage the designer to add more area when only looking at the area based results, which leads to a lower value per square meter but increases the total I_{LC}.

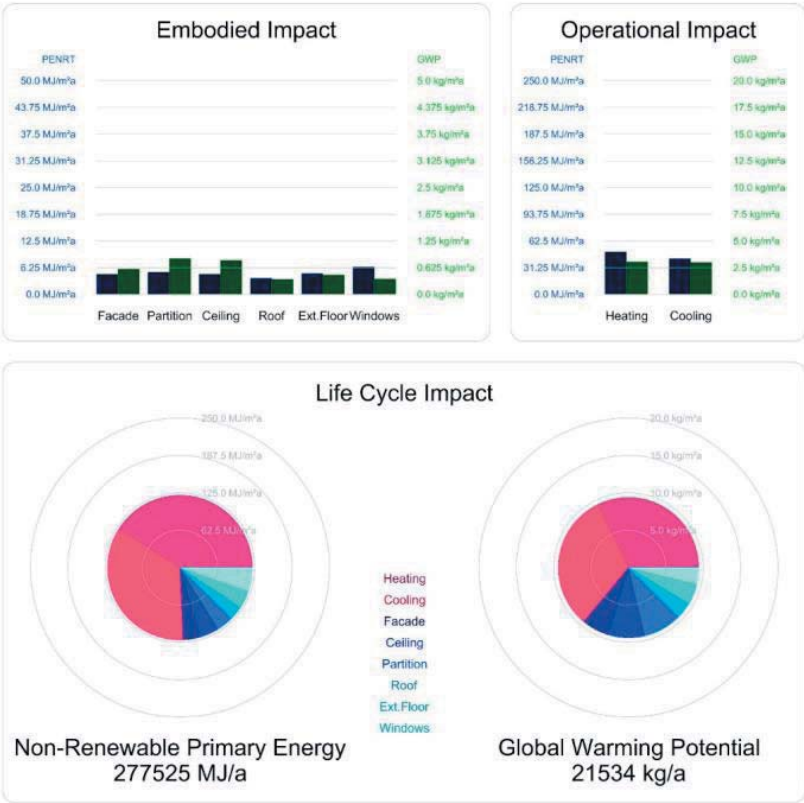

Fig. 4: Visualisation of Results

2.3 Application by students

The nine students received a short introduction to “Rhinoceros”, which none of them had worked with before. The reference service period was set at 50 years and in order to simplify the input and ensure the comparability, internal gains are assumed to be the same for all designs. The internal gains of a multi-family house – 90 W/m² per day according to DIN V 18599-10 [27] – were assumed, even if the intended use of the building was different. An individual setting of internal gains would have made a comparison between the designs too complicated.

The procedure for the semester was divided into two parts. In the first part, the students were supposed to analyse their proposed geometry and vary it in order to lower their I_{LC}. The following standard construction was assumed: The exterior walls and ceilings consist of concrete and the whole building envelope is equipped with 6 cm of EPS insulation. Data for these materials is included in the tool, in the form of default values.

In the second part the students were asked to vary the building materials and minimize the I_{LC}. The drop-down menu offers a range of typical building material. To select special materials, the students were allowed to use the environmental data from environmental product declarations and to integrate the new material into their designs.

3. Results

3.1 LCA Results

The students were asked to present and to explain their results every week. At the beginning some difficulties in modelling the geometry were observed. For the simulation with EnergyPlus all thermal zones need to be closed and the surrounding conditions have to be correctly assigned. In addition, the tool had to be slightly adapted during the process. As a result, the influence of changes to the geometry could not be assessed properly.

At the end of the semester all students were familiar with the tool and able to insert their individual materials. The results for the default and individual material are shown in Fig. 5. The graphs show similar profiles and a visible improvement after entering the own material. The main differences in the values for the entire building result from the differing building sizes.

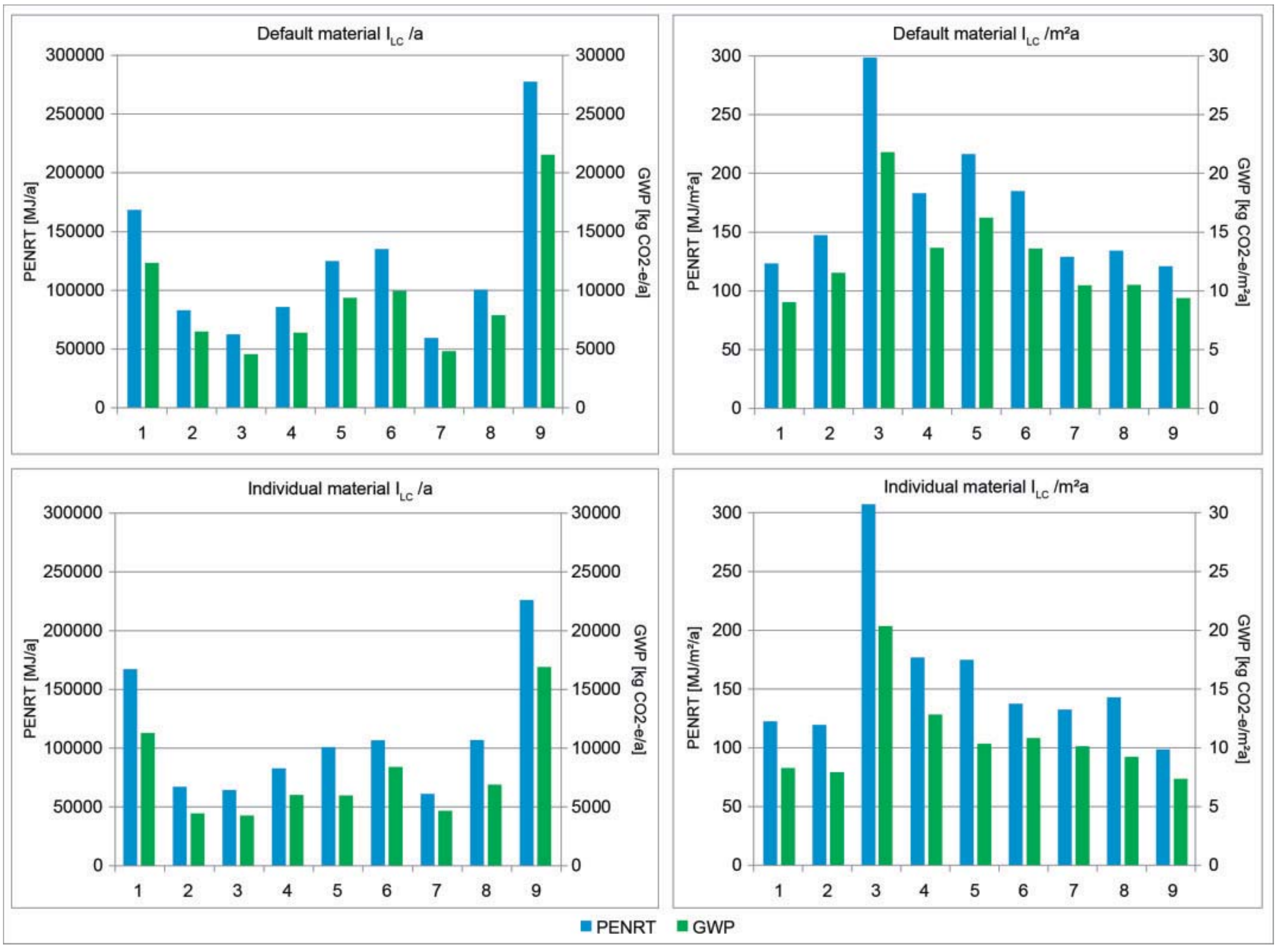

Fig. 5: Results per m² and whole building for default material and individual material (group A)

The improvement of I_{LC} through choosing the individual materials is shown in Fig. 6. The students of group A were able to save an average of 8.2% of PENRT and 16.2% of GWP. Most of the savings of GWP could be achieved in design 5. The student mainly employed wooden components. Design 7 shows no significant change in I_{LC}. Due to aesthetic reasons the student wanted to employ exposed concrete. Since concrete had already been the default material, it´s not surprising that the results are very similar.

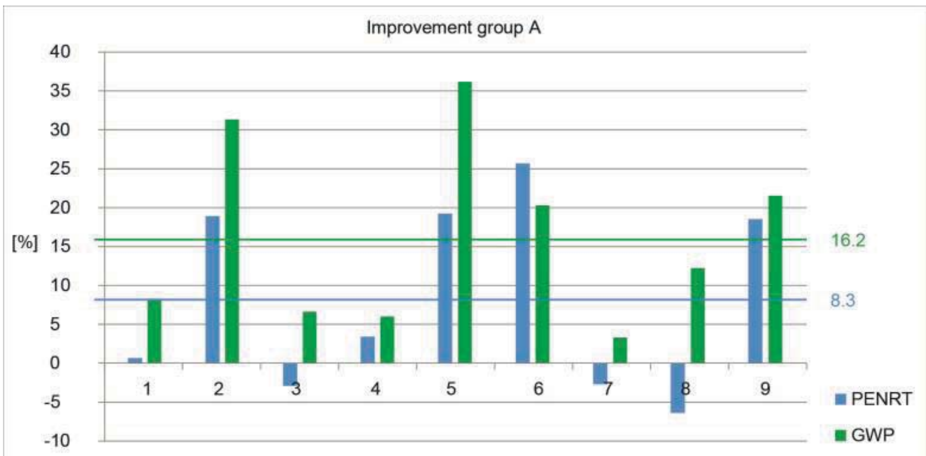

Fig. 6: Improvement through individual material with both indicators (group A)

3.2 Comparison to the reference group

The designs of a second group (group B) of 17 students who did not apply the tool are used as a comparison. The final geometry at the end of the design process is modelled with the default and individual material. The results in Fig. 7 indicate that most designs perform better with the default material. On average, the individual material causes 30.7% more PENRT and 16.9% more GWP.

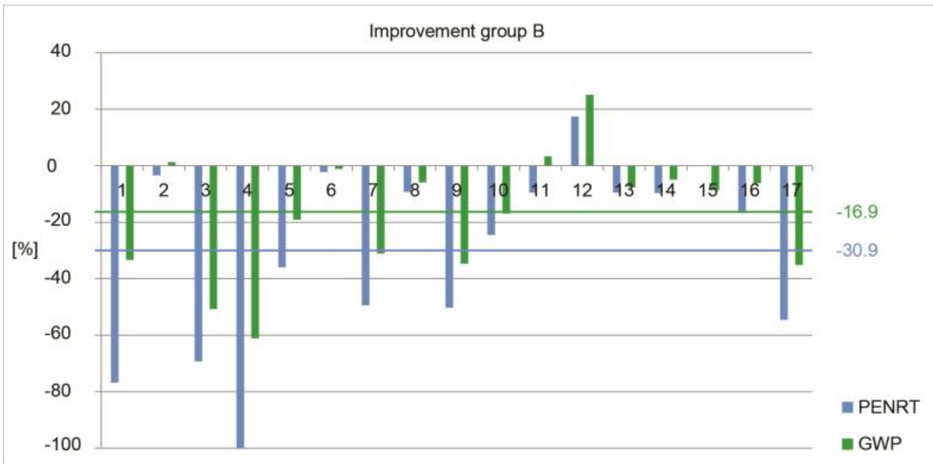

Fig. 7: Improvement through individual material with both indicators (group B)

3.3 Individual projects

Three projects of group A (see Fig. 8) are presented in more detail:

Project 3: This open structure covers the complete site and consists of prefabricated concrete elements. The columns of the arcade-like pergola support a light roof made of textiles to provide shade. There is only few enclosed space in the form of functional boxes made of stone, wood or glass. The pattern can easily be extended and the functional boxes can be changed.

Project 5: This project is located on a site currently occupied by a former cinema with natural stone walls. This design for a new market hall proposes to dismantle the existing roof and to cover the site with a timber frame roof. The old walls will remain and connect the new architectural elements with the surrounding buildings.

Project 9: This project provides a lot of enclosed space, but it also needs a lot of material, which results in the highest I_{LC} of all projects (see Fig. 5). Nevertheless, it achieves the lowest I_{LC}/m². The building provides various passive approaches for climatisation, e.g. cross ventilation.

Project 3 Project 5 Project 9

Fig. 8: Perspectives of three exemplary student projects

4. Discussion

4.1 Results of the group

The results are discussed separately for the two parts of the semester. During the first part, the students' difficulties to model their designs correctly prevented them from improving the design according to the LCA results. The objective to assess how much influence changes to the geometry have on the LCA could therefore not be achieved.
The results of the second part show that all students who applied the tool were able to reduce the environmental impact of their design – or at least to keep it at the same level – through the choice of material. The savings of an average of 8.2% of PENRT and 16.2% of GWP show a significant improvement, considering that the students were not experts, neither in building simulation nor in LCA. The benefit of employing this tool to analyse the environmental impact during planning is shown when comparing the results to the ones of group B, the students who did not apply the tool. Only one student received better results through the choice of material, four stayed within the same range, but eleven students increased the environmental impact.
The majority of the students in group A only compared two or three variants, which leads to the assumption that further improvement would have been possible if more variants had been assessed. When modelling a new variant, the students had to click a button in GH to start the new simulation. Depending on the size of the building and the performance of their computer, the simulation took between 40 seconds and 5 minutes. Although this computation time seems short enough, it proved to be a barrier to analyse more variants. This fact shows the demand for result feedback in real time.

4.2 Individual designs

Project 3 only integrates small conditioned boxes into the structure which provides shade and so in the climate of Southern Turkey the space can be used during the most time of the year. The LCA tool only takes into account the conditioned floor area, which results in a very high I_{LC}/m^2. In this case the evaluation based on area is questionable. For the total I_{LC} this project shows the lowest impact although it covers more space than most of the other projects.

Project 5 illustrates the possibility of deceasing the I_{LC} through the application of the LCA tool best. The change of the material from concrete to wood heavily reduces the GWP but also the PENRT. The improvement reduction of the environmental impact was achieved in this project.

The student who designed project 9 employed the LCA tool to compare different geometric variations and finally opted for a solution with shaded courtyards on both ends. She was able to lower the I_{LC} effectively by optimizing the orientation of the building within the urban context. The improvement shown in Fig. 6 lies above the average and could be achieved through optimizing the level of insulation and through employing timber ceilings.

The application of the tool demonstrates how important the choice of building material is. In addition, a visit of the historic city of Tarsus inspired most of the students to use local, traditional building materials. With the aid of the tool they were able to prove that the environmental impact of their material choice is lower than the one that common building materials have. This motivated them to face challenges resulting from the use of such material, e.g. weatherproofing of rammed earth or wood.

5. Conclusion

In general, the tool was accepted as a support for design decisions by most of the students, although some difficulties in the beginning of the semester appeared. The methodology of LCA was understood by all of them.

The tool is the first of its kind that allows simultaneous optimisation of operational and embodied impact. Thanks to the parametric model, variants can easily be compared. Compared to other LCA tools, which usually require manual input in tabular form, the process of conducting a building LCA is simplified. The reduction of the environmental impact in the students' projects shows that optimization is achievable by non-experts in the field.

The problems during the first part of the semester solely resulted from input problems. This shows the demand for very simple graphical user interfaces and methods for inputting the geometry. One possibility could be intuitive tools, e.g. SketchUp [28]. For the early design stages the level of detail that these tools afford is sufficient.

Although the computation time for the simulation with EnergyPlus ranged from only 20 seconds to 3 minutes, this proved to be too long. As a result, the students analysed only a few design variants and possibly they did not achieve the optimum variant they could have obtained by comparing more of them. This shows the demand for real time methods when calculating the energy demand of a building design. A possibility is the application of quasi-steady state solutions that calculate the energy demand on a monthly basis as shown in [29].

To advance sustainability in architecture, we propose the following supplementations to the architectural design education:

1. The teaching concept should include LCA and building performance analysis. The students should be reminded regularly that future architectural planning very probably will not be possible without taking into account the environmental impact.
2. The same way as CAD tools, analysis tools like the LCA tool presented here should be taught early in the period of study.
3. The analysis should have a noticeable effect on the evaluation of the students' designs.

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Asphalt Solar Collectors contribution to the Urban Heat Island Effect under Hot Arid Climate Conditions

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Summary

Asphalt solar collector (ASC) is a novel technology that is used to capture the solar energy from paved roads for low to medium temperature solar thermal applications. However, asphalt paved roads are also one of the main contributors to the urban heat island effect. This study assesses the impact of the ASC technology on the thermal behaviour of the asphalt roads and consciously on the urban heat island effect. In the research an ASC system is developed and its performance under the load of an absorption cooling cycle, an atmospheric water generator and domestic hot water demand is analyzed and evaluated along with each load impact of the on the asphalt surface temperature under the typical hot arid climate conditions of the city of Jeddah.

Keywords: Asphalt solar collector, solar energy, urban heat island, Jeddah

1. Introduction

Asphalt Solar Collectors (ASC), i.e. the use of asphalt paved surfaces as solar collectors to harvest the solar energy, is a comparatively 'young' technology that has started to capture the interest of researches in the past few years. A basic ASC system consists of an asphalt pavement and pipe embedded in to the wearing course of the asphalt pavement, which is the Heat exchanger part. An ASC functions by pumping a fluid through a pipe embedded in the asphalt paved road that is exposed to the environment. The fluid temperature rises as it collect the heat from the asphalt pavement and the heated fluid is collected in storage tanks for further use.

The ASC technology is attractive mainly for two reasons: 1. the thermal properties of asphalt, and 2. the abundance of the asphalt infrastructure in modern cities as some 35 to 60% of a modern city is already paved with asphalt [1] and it is resurfaced in average every 12 to 20 years [2:92]. Thus, asphalt solar collectors (ASC) can be relatively easily integrated in the current infrastructure. Moreover, capturing this excess energy can help improve the life span of the paved road by reducing the asphalt rutting[3] and allow utilizing the captured excess energy in a meaningful manner. Also, filed tests on similar systems have showed that a well designed ASC system have no negative impact on the paved road structural performance [3, 4].

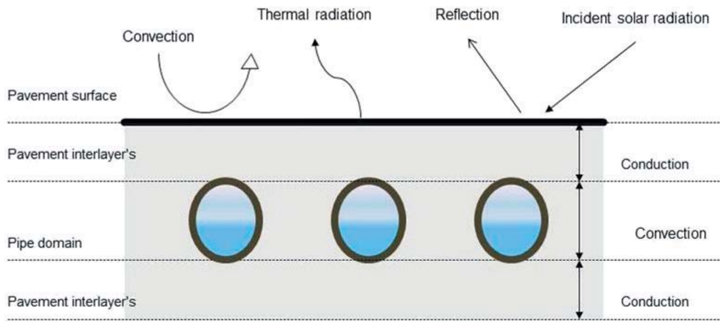

Figure 1: Heat transfer mechanisms in an asphalt solar collector (ASC)

Apart from some simple lab tests[5], the contribution of functioning ASC on the urban heat island as well as its possible applications are to date not well documented [6]. The asphalt paved roads are one of the main contributors to the UHI effect [7] which can lead to an increase of up to 18 % in the cooling demands especially in hot arid climates[8]. Therefore, this paper will explore the impact of functioning ASC system on asphalt surface temperature and consequently the technology's contribution to the urban heat island effect and assess wither the ASC can be also used as a heat island mitigation tool in the same time.

The use the ASC for solar thermal applications and as a heat island mitigation tool in the same time represents a paradox by itself. On the one hand, the design of the ASC is optimized in order for that the asphalt reaches higher temperature in order to for the system to be able to collect more energy, resulting in the delivery of higher exergy content for the solar energy applications. On the other hand, when the ASC is used as a urban heat island (UHI) mitigation measure, it is required that the system maintains the asphalt surface temperature at low temperatures, which, in turn, would constrain the heat exchanger system's ability to reach high temperatures in the outlet, thus rendering the energy collected not useable in other applications. Therefore this paper will assess the ASC contribution to the UHI in by means of exploring the resulting surface temperature of an optimized ASC for three applications; Absorption solar cooling, Atmospheric water generation and for domestic hot water applications under the hot arid climate conditions

2. Methodology

The research is conducted with the help of the numerical simulation software TRNSYS under the hot arid climate conditions where the ASC potentials can be fully exploited. The typical meteorological year (TYR) weather data of the city of Jeddah, Saudi Arabia is chosen for this research as its climate conditions reflect a typical hot arid climate. The city is located on the shores of the Red See on the west side of the Kingdom of Saudi Arabia (latitude 21°29'N, longitude 39°9'E) south to the Tropic of Cancer. Jeddah is classified climatically as an arid desert hot climate (Bwh) [9:1637]. This climate is characterized by hot to extremely hot summers and mild to warm winters. Rain is scarce and the sky is clear all year with minimal cloud cover. As it is typical with this type of climate, the temperature and the solar radiation intensity are at their maximum during the six months period between April and September. The analysis is therefore focused on this period of the year as ASC performance and the UHI are at their peak.

To validate the accuracy of the simulated model, an asphalt model is built in the software using the thermal and physical properties of real sample from the case study site, a comparison between the thermal behaviour of modelled asphalt against real measurements taken from the same climatic zone is done to insure that modelled sample behave similarly to the real one.

Afterwards, an optimized configuration of the ASC components is developed, the ASC system components along with the asphalt thermal properties are chosen based on previously published articles on the topic[6, 10-12]. The asphalt pavement and the heat exchanger are subjected to a sensitivity analysis in order to develop the optimized ASC model that can yield the largest amount of useful energy for low to medium temperature solar thermal applications. The sensitivity analysis investigates the properties of the asphalt pavement with the addition of the road rated insulation Styrodur®C 4000 CS, with a of conductivity (λ) = 0.032 W/m*k[13]. The other investigated aspect of the ASC is the heat exchanger part (pipes and fluid) of the system

Table 1:Investigated asphalt and heat exhanger properties to develop the optimzed ASC system

Variant number	Wearing course Conductivity (λ) [W/m*K]	Insulation Thickens[cm]	Insulation Depth from surface [cm]	Wearing course Heat capacity (Cp) [kJ/kg*k]	Wearing course ab-sorptivity(α)
1	2	0	0	0.8	0.86
2	2.5	3 cm	5 cm	0.9	0.88
3	2.88	4 cm	13 cm	1	0.90
4	-	5 cm	-	1.1	0.92
	pipe material λ [W/m*K]	Pipe Spacing [cm]	Pipe Depth [cm]	Pipe Diameter [cm]	Flow rate [kg/h]
5	Copper (401)	10 cm	3 cm	1 cm	400
6	Steel (54)	15 cm	4 cm	2 cm	600
7	PEX (0.47)	20 cm	5 cm	3 cm	800
8	PVC (0.19)	-	-	-	1000

The ASC optimization is achieved by assessing the impact of each ASC system component on the performance of the ASC as per the following criteria:

- The amount of fluid collected at temperatures between 45 °C and 55 °C at 2.5 k intervals along the simulation timeframe
- The maximum temperature reached by the fluid at the outlet.
- The maximum temperature difference between the inlet and outlet.
- The amount of heat harvested by the ASC , q = $\frac{V*Cp*\Delta T}{A_{slab}}$ [W/m2] (1)
- The system efficiency, η = $\frac{\text{the extracted heat in W/m2}}{\text{global solar raditon on the horizontal W/m2}}$ [%] (2)

Table 2: Summary of the simulation boundary conditions

	Simulation time frame	Fluid Pumping regime	Weather file	Inlet water temperature	Asphalt area
Boundary condition	From 1st of April to 30th of September with a 1 minute simulation time step	From sunrise to sunset	(TYR) Jeddah	Mains water temperature from weather file	20 m2

Supporting components such as the storage tank, power source and a DC pump are added to the ASC system as displayed in figure 2.

2.1 Water tank properties

A vertical insulated hot water tank is used in the simulation. The tank height is 2m its capacity is 3 m^3. The tank heat loss coefficient value is 0.1 [W/m^2*K].

2.2 Water pump properties

A direct current (DC) water pump with a rated capacity of 1000 Kg/h is used. The main advantage of the DC pump is its high efficiency and the fact that the pump can be directly wired to a PV panel without the need of an additional DC/AC converter. This variant is most appropriate as the ASC system is expected to work in phase with the sun radiation intensity, thus rendering the use of a backup battery as unnecessary.

Table 3: Specifications of the water pump [14]

Pump	Pump type	Rated voltage	Rated power	Current consumption	Max Head	Max flow rate	Max fluid temperature
Spec.	centrifugal	12V DC	13 (W)	2 max (A)	2 (m)	1020 (L/h)	100 °C

2.3 Photovoltaic panel properties

A 12v 30WP photovoltaic panel is chosen as the power source for the pump. The PV panel is installed facing the horizontal radiation. This angel is the optimum angle for PV panels during the summer months in Jeddah [15:48] and the working hours of the pump.

Table 4: Specification of the PV panel [16]

PV	PV type	PV peak power	Cells number	efficiency
Spec.	Monocrystalline	30 (WP)	36	16.1%

2.4 Heat exchanger

An Air to water heat exchanger is used to mimic the effect of the load of each of the three applications on the return water temperature to the storage tank. The heat exchanger is used as it's a stabile system and can be easily specified and controlled, thus it can be integrated into a further filed tests under real conditions. The heat exchanger performance is recalculated separately in each of the three scenarios using the number of Transfer Units effectiveness method (NTU)[17]. The NTU value is used in order to regulate the amount of heat extracted from the water by the heat exchanger and consequently delivering the return water from the heat exchanger to the tank with the right temperature as if the water was subjected to real load.

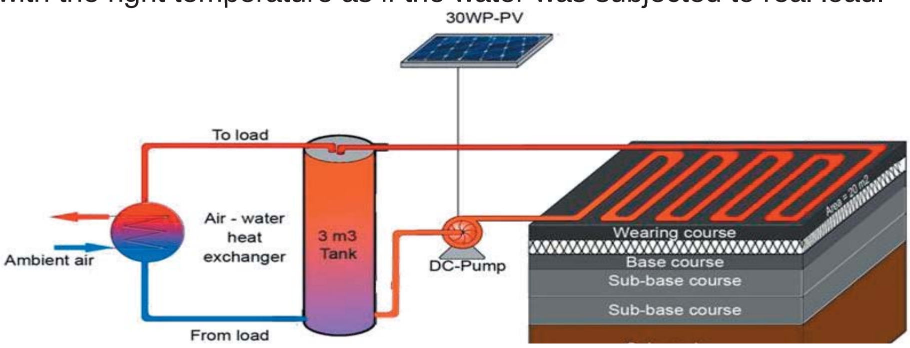

Figure 2: The ASC system with the supporting components

2.5 Assessment of the UHI under ASC Load scenarios

To assess the contribution of a functioning ASC on UHI, the surface temperature, and the profile temperature of the asphalt to the depth of 78 cm underground is simulated with the system working to meet the load of three applications namely:

- A 2kW Absorption solar cooling (AC)
- Atmospheric water generation (AWG) with a water extraction efficiency of 35% [18]
- Domestic hot water demands(DHW) of 600 Liter/day which reprresnt a consumption of about 10 persons[19].

Table 5: ASC applications simulation boundary conditions

Application	Minimum driving temperature	Maximum driving temperature	Load hours	ΔT supply and return temperature	Heat exchanger NTU
AC	65 °C	-	9 am to 6 pm	5K [17]	15%
AWG	60 °C	-	2 am to 8 am	5K	21%
DHW	55 °C	60 °C	8 pm to 9 pm	-	100%

The maximum and minimum driving temperatures of each system are specified based on published working temperature of each system [18, 20, 21]. The AC load hours are chosen between 9am to 6 pm as they represent a the typical cooling demand, where the AWG load hors are chosen between 2 to 8 am, as in this time, the relative humidity is at its highest, thus allowing the system to extract the largest amount of water from the air.

The asphalt pavement temperature with an ASC system working under three different scenarios is compared to the temperature profile of a normal asphalt pavement. the weather conditions of the last week of May, during which the asphalt reaches its highest temperature, is chosen as reference week for all the simulation, the reference week results are used to build an average 24 hour asphalt temperature profile up to a depth of 78 cm below the asphalt surface. The ASC performance meeting the three applications loads is evaluated based on the following criteria:

- The ASC system working hours
- Amount of water collected above minimum driving temperature
- The amount of heat harvested by the ASC , $q = \frac{V * Cp * \Delta T}{A_{slab}}$ [W/m2] (1)
- The system efficiency, $\eta = \frac{\text{the extracted heat in W/m2}}{\text{global solar raditon on the horizontal W/m2}}$ [%] (2)
- The system working fraction , $f = (\frac{working\ hours}{\text{load hours}} \text{ x } 100)$ [%] (3)

3. Results

3.1 Provisional validation of the simulated asphalt model

Asphalt paved road consists of a number of layers each having its distinct properties that depend on a large number of factors, such as the type of the aggregate and thickness, etc. Therefore, having the exact data for each layer is necessary in order to create a realistic model of the asphalt pavement in simulation. Such data is a available in Alwai (2012) [12] paper regarding the heat distribution in asphalt roads in the city of Mecca, which is located some 70 km to the southwest of Jeddah, thus it can be safely considered a valid alternative data source for this validation.

Table 6: Asphalt properties as found in Alawi [7] study and used to build the TRNSYS model

Layer	Thickness (m)	Thermal conductivity λ (W/m*K)	Heat capacity Cp (kJ/kg*k)	Density ρ (kg/m3)
Wearing course	0.05	2.5	1	2300
Base course	0.08	1.8	1.1	2200
Sub-base course	0.25	1.8	0.9	2200
Sub-grade course	30	1.5	0.85	1500

The difference in the temperature between the simulated and measured ones is 5K in average. The variation of the temperature can be attributed to a number of factors, like the fact that the simulations are based on typical metrological year (TYR) weather data and not on real time weather data, also there is no data regarding asphalt sample length as well as its absorptivity value, which can highly impact the asphalt temperature. In general, The simulation results of the asphalt pavement show a general agreement with the results obtained by Alwai [12] and with Saudi Arabia asphalt grade recommendation map made by Al-Abdul Wahhab et al 1995 [22] and therefore, can be safely considered valid for the scope of this research.

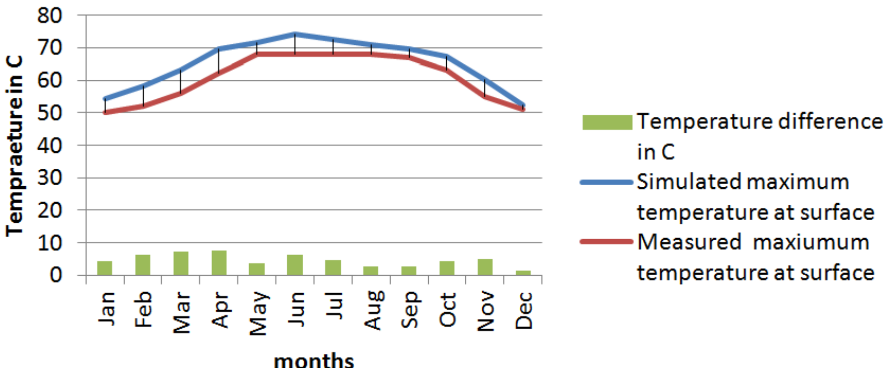

Figure 3: Simulated and measured monthly maximum temperature of the asphalt surface

3.2 Development of an optimized ASC configuration and its performance meeting the loads from the month of May

The sensitivity analysis revealed that the heat insulation and the asphalt heat capacity had the most positive impact on the temperature difference between the fluid inlet and outlet temperatures. Increasing the fluid flow rate had, on the other hand the most negative impact on the same criteria, followed by increasing the system depth and the pipe spacing. The asphalt conductivity and solar absorptivity showed very little influence on the system performance. Increasing the heat insulation thickness made a slight impact on the system performance. The results are used to develop an optimized ASC system as follows:

Table 7: Asphalt properties used in the optimized ASC model

Asphalt course	Thickness (m)	Solar absorption coefficient (α)	Thermal properties		
			λ (W/m*K)	Cp(kJ/kg*k)	ρ (kg/m3)
Wearing	0.05	0.9	2.5	0.9	2300
Insulation	0.03	-	0.032	1.47	38

Table 8: heat exchanger properties of the optimized ASC model

Asphalt course	System Area (m^2)	Pipes depth (m)	Pipe wall conductivity (W/m*K)	Specific heat of fluid (J/Kg k)	Flow rate (kg/h)	Pipe geometry		
						Spacing (m)	Diameter (m)	Thickness (m)
Wearing	20	0.03	0.47	4.188	875	0.1	0.02	0.002

Table 9: Performance of the optimized ASC

Month	Avg. Tank Temp.	Max Tank top temp.	Min Tank top temp.	Amount of water pumped from the tank to ASC	Avg. efficiency	Avg. Heat gain
	°C	°C	°C	Liter/m^2	%	kW/m^2
May	67.70	71.77	59.88	1490.4	6.0 %	56.92
June	68.03	70.22	66.19	631.5	4.48%	41.77
July	68.62	71.08	67.03	891.7	5.72%	48.21
Aug.	68.57	70.94	66.80	907.8	5.65%	46.1
Sep.	67.78	70.49	66.30	685.42	3.79%	32.65

Table 10: Performance of the optimized ASC meeting the three loads for the month of May

Load Type	Avg. Tank Temp.	System working hours.	System working fraction	Amount of water collected above minimum driving temperature	Avg. system efficiency	Avg. Heat gain
	°C	h	%	Liter/m^2	%	kW/m^2
AC	64.7	91	34	2492	12%	110
AWG	62.1	163	91	3502	16%	148
DHW	56.3	58	97	3028	22%	199

3.3 Assessing the ASC impact on the asphalt temperature profile

The temperature profile of the asphalt pavement from the surface the sub-grade course at a depth of 78 cm below surface is simulated. The depth of 78 cm below the surface is considered sufficient, as at that depth no noticeable temperature fluctuations occur anymore.

The comparisons between the asphalt temperature with or without an installed ASC system are carried out for the last week of May. The result shows that the asphalt temperature in all cases reached its maximum temperature at 4 pm. The surface temperature of a normal asphalt pavement without an installed ASC system reached a maximum temperature of 63.5 °C. this surface temperature is exceed by the surface temperature of the asphalt pavement with an installed ASC working to meet the 2kW absorption solar cooling (AC), here the surface temperature reached a maximum of 71 °C, followed by the surface temperature of the pavement with an installed ASC working to meet the Atmospheric water generation (AWG) load with a maximum of 67.8 °C. The surface temperature of the pavement with an installed ASC working to meet the DHW recorded the lowest temperature between all the scenarios with a maximum surface temperature of 61.7 °C. The average surface temperature of the all the variants hovered around the 44.5 °C with the exception of the AWG scenario with an average of 43.6 °C.

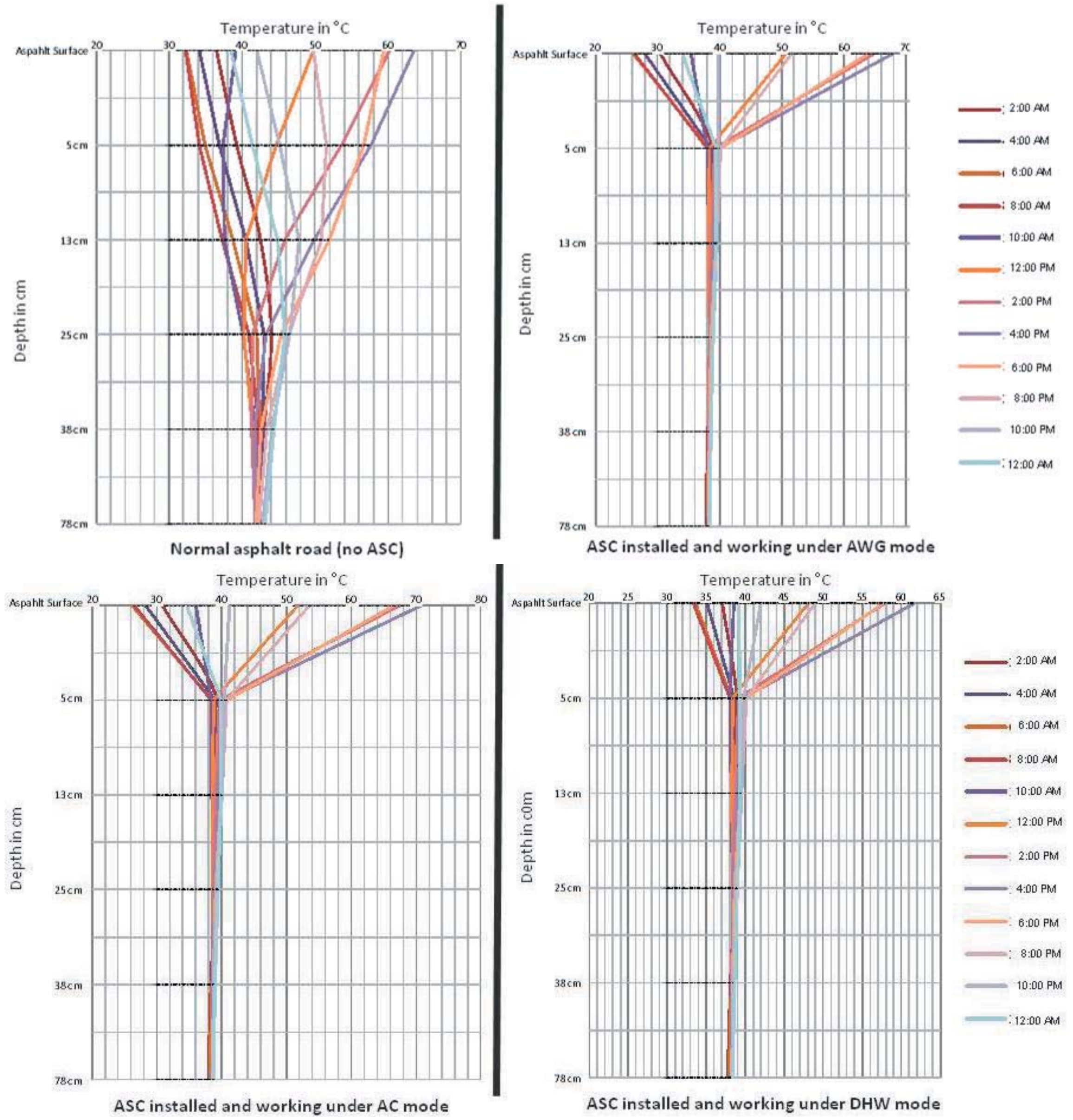

Figure 4: Asphalt temperature profile in the last week of May for the four investigated variants

4. Discussion

The research showed that, the heat exchanger part of the ASC (pipes and fluid) has a greater influence on the performance of the ASC over the asphalt thermal properties. The main ASC design consideration that had the greatest impact on the system performance are: the flow rates and the depth of the heat exchanger and depth of that insulation layer depth, respectively.

The results of investigating the ASC performance under the loads reveal good potentials for the use of the ASC technology for covering the domestic hot water demand and for atmospheric water generation. The system efficiency reached 22% with the system working under the domestic hot water demand mode. As an atmospheric water generator; the investigated 20m^2 ASC system was able to extract a total of 1160 liters of water from air for the month of May.

However, it is important to note that designing a specified load for each of the previous mentioned cases was beyond the scope of this research. However, they show the need of future field test in order to assess accurately the applicability of the ASC system to meet such demands and to validate the results acquired in this research. Nevertheless, the results obtained in this research demonstrate a wide array of potential application for the ASC that require further research.

The contribution of the ASC to the urban heat island is assessed basing on the surface temperature of asphalt pavement with and without the ASC. The results showed that the ASC functioning to meet the load of the atmospheric water generator and the domestic hot water demand had neither a positive nor negative impact on the UHI, as the maximum surface temperatures in both cases was slightly below or above the surface temperature of a normal paved asphalt surface. And in all cases the 24h average surface temperature remind almost identical in all scenarios. However, this was not the case when the ASC is working to meet the load of an absorption cooling cycle as the surface temperature of the asphalt was around 8K over the maximum surface temperature of a normal pavement. Due to the weak performance of the ASC meeting the AC load, such an application can be considered not suitable for ASC systems.

In conclusion, the results indicate that a careful consideration needs to take place when designing the ASC so that it can meet its required performance demand and not contribute negatively to the UHI phenomena. The results can be understood as all the investigated solar thermal applications require driving temperatures above 60°C.

The system affect on the roads safety and the ability of the system to be integrated in other large scale infrastructures hot arid climates are not demented and need to be included in further filed test research for the use of ASC along with a cost-benefit analysis.

5. Conclusion and future research

In this paper an optimized asphalt solar collector along with necessary supporting components is developed based on a sensitivity analysis and widely available commercial devices. Thus, allowing building a real system based on the given specifications for further field tests in the future to validate the research results. The performance of the developed system under the load of an absorption cooling cycle, an atmospheric water generator and domestic hot water demand is analyzed and evaluated along with each load impact of the on the asphalt surface temperature for the last week of May under typical hot arid climate conditions. The system achieved a maximum efficiency of 22% meeting the DHW load in the observed simulation timeframe.

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Assessing the Sustainability Performance of Sports Facilities – Methodology and Case Studies

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Summary

Up to now, a holistic assessment methodology for the sustainability performance of sports facilities is not available. Therefore, this paper presents a methodology developed specifically for sports facilities and shows the results of a case study. On the basis of selected examples it is demonstrated how the developed 36 criteria address the specific characteristics of sustainable sport halls by their subindiactors. The presented methodology, so far developed for stadiums and sports halls, may be a driver of sustainable building regarding sports facilities in the future.

Keywords: Sports Facilities, Sustainability Assessment, Pilot Cases, Sports Halls, Stadiums

1. Introduction

In recent years, assessing the sustainability performance of buildings became a common practice in today's construction industry. Labels like LEED, BREEAM or DGNB are widely used to assess the performance of an even wider range of building types such as offices, hotels, residential and educational buildings. However, up to now a holistic assessment methodology for the sustainability performance of sports facilities is not available, although the organisers of mega sport events are under constant pressure to report on the sustainable performance of their venues. Previous methods like the 'BREEAM for Olympic Park and Venues' developed by BRE for the Olympic Games in London did not offer a holistic methodology [1] and a comparison of the sustainability performance for sport facilities is not yet possible.

Therefore the objective of the present paper is to show a set of criteria and indicators designed specifically to assess the sustainability performance of sports facilities for different applications:
stadiums and sports halls. The methodology is developed by a joint German and Austrian working group under the initiative of the Austrian Sustainable Building Council (ÖGNI) and the German Sustainable Building Council (DGNB). Accordingly, the study considers Austrian and German standards as well as guidelines from associations and federations. There have also been previous studies by the authors which have been taken into account, such as the dissertation 'Sustainability of Olympic Venues" that was published in 2010 [2] and the research project 'Guidelines for Sustainable Venues of Mega-Events" that was supported by the BMWi (Federal Ministry for Econom-

ics and Technics) from 2012 to 2013 [3]. To demonstrate its suitability for the application, several case studies have been conducted and are shown in this paper.

In summary, the contribution of this study is obvious as the resulting outcomes can be applied for assessing the sustainability performance of sports facilities.

2. Methodology

The main objectives of this research project were the derivation of criteria for sustainable sport venues and the design of indicators for the application to stadiums (type I) and sports halls up to 200 spectators (type II).

2.1 Defining the Main Criteria

First step of the study was to determine the set of indicators for the sustainability assessment for sports facilities. A working group for sustainable sports facilities named 'AG Sportstätten' under the lead of Prof. Natalie Essig was established to investigate all different approaches for buildings sustainable sports facilities: Property owners, architects and planners, representatives of associations and federations, political and economic representatives, researchers as well as members from the DGNB and ÖGNI took part in defining the set of criteria.

The OPEN HOUSE and DGNB six pillars model was chosen because it covers all categories of sustainability in regard to buildings.

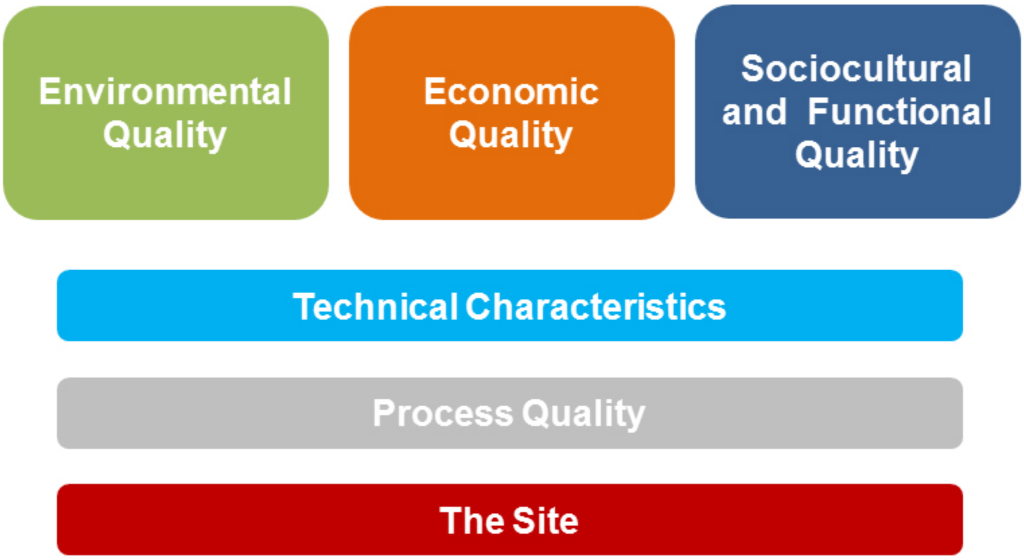

Fig. 1 Sustainability categories, six pillars model [4]

Besides previous studies by the authors ([2] and [3]), the defined set of indicators was based on existing schemes for assessing the sustainability performance of different building types as shown in table 1.

Table 1 Certification Schemes analysed

Certification Scheme	Developed by	Published in
DGNB Core for Offices (international use)	DGNB	2014
DGNB for Assembly Buildings	DGNB	2012
DGNB for Retail	DGNB	2015

DGNB for Hotels	DGNB	2015
DGNB for Offices	DGNB	2015
DGNB for New urban districts	DGNB	2012
DGNB for Education facilities	DGNB	2015
Buildings in Europe	OPEN HOUSE Consortium	2013
LEED Core and Shell	U.S. Green Building Council	2013
BREEAM for Olympic Park and Venues	BRE Global Limited	2011

2.2 Defining the Subindicators

After defining the criteria they were divided into subindicators. For most of the indicators, it was separated between the application to stadiums (type I) and sports halls (type II) due to different scales and approaches as well as guidelines. As mentioned before, type II refers to sport halls up to 200 spectators. The subindicators were developed by the experts from the specific sectors of the working group as well as the planners of the case studies to ensure the direct application. The authors guided through the working process as working group leaders and insured the quality of the project.

For utilizing the method in Austria as well as Germany, Austrian and German standards have been taken into account. Whereas for example office buildings have to fulfil requirements regarding lighting, temperature and ventilation according to the German 'Technische Regeln für Arbeitsstätten (ASR) [5], the normative requirements for sports halls in Germany are given with the DIN 18032 'Sports halls - Halls and rooms for sports and multi-purpose use' [6]. Moreover, guidelines from associations and federations such as

- International Federation of Association Football (FIFA)
- and Union of European Football Associations (UEFA)
- as well as Deutscher Olympischer Sportbund (DOSB),
- Deutscher Fußball-Bund (DFB)
- and Österreichischer Fußball-Bund (ÖFB),
- Bundesinstitut für Sportwissenschaft (BISp)
- and Österreichisches Institut für Schul- und Sportstättenbau

have been considered.

The rating was done according to the procedure of DGNB with 10 percent as minimum reflecting the required performance by law and 100 percent (max.) for best practice (see fig. 2).

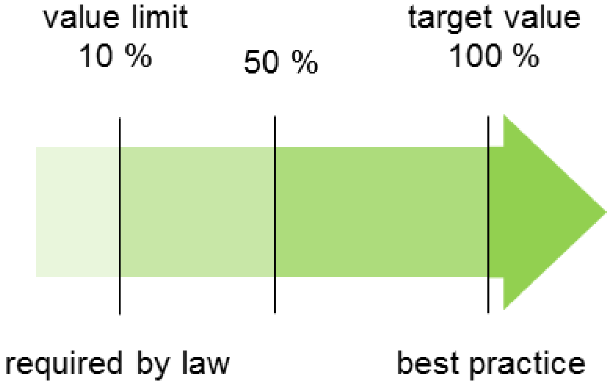

Fig. 2 Rating scale

Additionally, the weighting of the indicators also differs for type I and type II as for example the thermal comfort is of greater significance for sports halls than for stadiums.

3. Results

3.1 Main Criteria

The results of the present study are in summary a set of 36 criteria as shown in table 2. As can be seen from the table, there are some significant differences to the certification schemes analysed (table 1). The indicators ‘Light Pollution’ (ENV 1.4) and ‘Noise Prevention’ (TEC 1.7) were added as these topics are of specific interest when assessing sports facilities

Table 2: Set of Criteria for Sustainable Sports Facilities

Number	Criteria	Category
ENV 1.1	Life Cycle Impact Assessment	
ENV 1.2	Local Environmental Impact	
ENV 1.3	Responsible Procurement	
ENV 1.4	Light Pollution	Environmental Quality
ENV 2.1	Life Cycle Impact Assessment - Primary Energy	
ENV 2.2	Drinking Water Demand and Waste Water Volume	
ENV 2.3	Land Use	
ECO 1.1	Life Cycle Cost	
ECO 2.1	Flexibility and Adaptability	Economic Quality
ECO 2.2	Commercial Viability	
SOC 1.1	Thermal Comfort	
SOC 1.2	Indoor Air Quality	
SOC 1.3	Acoustic Comfort	
SOC 1.4	Visual Comfort	Sociocultural and Functional Quality
SOC 1.6	Quality of Outdoor Spaces	
SOC 1.7	Safety and Security	
SOC 2.1	Design for All	
TEC 1.2	Sound Insulation	
TEC 1.3	Building Envelope Quality	
TEC 1.4	Adaptability of Technical Systems	
TEC 1.5	Cleaning and Maintenance	Technical Characteristics
TEC 1.6	Deconstruction and Disassembly	
TEC 1.7	Noise Prevention	
TEC 3.1	Mobility Infrastructure	
PRO 1.1	Quality of Project Preparation	
PRO 1.3	Design Concept	
PRO 1.4	Sustainability Aspects in Tender Phase	
PRO 1.5	Documentation for Facility Management	Process Quality
PRO 1.6	Design and Urban Planning	
PRO 2.1	Environmental Impact of Construction	
PRO 2.2	Construction Quality Assurance	
PRO 2.3	Systematic Commissioning	
SITE 1.1	Local Environment	
SITE 1.2	Public Image and Social Conditions	The Site
SITE 1.3	Transport Access	
SITE 1.4	Access to Amenities	

3.2 Subindicators for sports halls (type II)

Sports facilities require specific conditions and characteristics. In the following some subindicators for type II (sports halls) will be described more in detail illustrated by some examples.

3.2.1 ECO 2.2 Commercial Viability

The aim of the criterion 'Commercial Viability' is to assess whether a building has the potential to respond to medium and long-term user demand in the relevant market. Concerning sports halls in particular the sports development planning is an important tool. With sports facility planning the needs of the current sports situation of a municipality can be identified and therefore an important basis for the design, construction and operation of sustainable gyms established [7]. Usually it includes an empirical inventory, the identification of the needs, the setting of targets and measures and the coordination with relevant stakeholders. A subindicator was added assessing the sports facility planning depending on the performed extend.

3.2.2 SOC 1.7 Safety and Security

A high sense of security makes a vital contribution to people's comfort. Therefore, the aim of the criterion is to assess measures taken to increase the sense of security and reduce dangers. For sports halls, besides safety in the event of fire, safe main paths, safety in case of unpredicted danger, the prevention of vandalism and the prevention of accidents when doing sports are important aspects. Therefore, two subindicators were added assessing the measures implemented to prevent vandalism (e.g. access concept or video-surveillance) and the security management in regard to the sports equipment (e.g. weekly visual inspection, monthly functional test and yearly general inspection).

3.2.3 SOC 1.4 Visual Comfort

The criterion 'Visual Comfort' assesses an adequate supply of daylight and artificial light in the interior sports hall. Therefore, the availability of daylight, the prevention of glare and the colour rendering is evaluated. For sports halls in particular subindicators are added to assess whether the lighting was planned in detail and includes special lighting for the spectators, measures to support inclusion were implemented (e.g. separately usable rooms for men and women).

3.2.4 SOC 2.1 Design for all

The aim is to make the complete built environment available to every person and make it possible for disabled people to participate fully in all aspects of life, also in doing sports. For evaluating the accessibility of the building an exclusion indicator was added, to check either if regional handicapped sports group were included and considered in the identification of the needs or if a concept for refitting for handicapped accessibility exists.

3.3 Case Study 'Sporthalle Zorneding'

The municipality of Zorneding decided early in the planning stage to implement their new triple sports hall 'as sustainable as possible' and to incorporate sustainability criteria of the Austrian and German Society for Sustainable Building (DGNB and ÖGNI) in the planning, construction and commissioning process. Since the beginning of the planning in 2011 the authors assisted the team of architects and specialist planners on sustainability issues. Therefore, the sports hall 'Am Sportpark' in Zorneding, finished in the end of 2014, represents an important contribution as a flagship project on sustainable building.

Fig. 3 Sporthalle Zorneding © PALAIS MAI GMBH ARCHITEKTEN STADTPLANER

Some key aspects of the positive result are demonstrated in the following:

3.3.1 Planning Process

The later users were involved in the planning and realisation process from the beginning and meeting the users' requirements was a key goal. Within the scope of a sustainable planning process the following measures were implemented:

- visits of other sports halls
- preparation of a booking plan of the future sport hall for estimating the real capacity
- performance audit and life cycle costing
- analysis e.g. simulations regarding energy efficiency and building services such as local heating, heating system for the hall, illumination, ventilation and heat insulation

3.3.2 Site

In the context of site selection specific site analyses have been carried out. After an intensive review process the present site besides the sports field area and the building yard, a fallow land directly beneath a former filled gravel pit, was chosen. As a result the project is a successful example of brownfield redevelopment.

3.3.3 Architecture

The sports hall was built as triple gym. The material and structural system is composed of a concrete-timber construction that is covered with wooden slats from the outside. The roof of the changing rooms and further adjoining rooms is designed as green roof. The extensive translucent glazing of the hall provides a pleasant, natural brightness in the hall interior and calls attention by externally visible light accents in the evenings.

3.3.4 Accessibility

The use of the hall by athletes with physical disabilities, such as wheelchair athletes, was considered as part of the early planning. Due to a current lack of demand the requirements have not been fully implemented but only pre-equipped. So if necessary, the changing rooms and showers can be retrofitted with little effort at any time for handicapped accessibility. A lift to overcome the lowering of the sporting field already exists.

Keys for entering the changing rooms can be borrowed on-site by an electronic access system. The system (BUS) also controls electrical door contacts at all access points of the hall, the room temperatures, window opening and operating conditions of the building services and can be monitored from the municipality's town hall.

3.3.5 Energy Efficiency

Well insulated exterior components and a sophisticated ventilation concept form the basis for low energy consumption and low maintenance costs. The sports hall is heated by a gas absorption heat pump in the base load. The intensive investigations for an alternative realization of a district heating network identified no effective use. The heating surfaces are designed for a low-temperature control and increasing energy efficiency. The heat is transmitted by radiant ceiling panels in the hall and by underfloor heating in the adjoining rooms. For ventilation, an underground duct provides tempered fresh air, precooling in summer and preheating in winter, and assures an annual thermal comfort.

The already mentioned translucent glazing promotes daylighting and thereby reduces the need for artificial light. Simultaneously, the special glass (profile) prevents glare of athletes by its opaque characteristics.

3.3.6 Materials

Only PEFC (Programme for the Endorsement of Forest Certification) certified wood and wooden products were used. The performed life cycle analysis (LCA) indicates a minor impact of the building on the environment over the entire life cycle. Indoor air measurements demonstrated a good indoor air quality in all sports rooms.

4. Conclusion

The present study was designed to determine the sustainability criteria of sustainable sport facilities. In summary, 36 criteria were defined to assess the sustainability performance of sustainable stadiums and sports halls. The paper shows how the specific characteristics of sustainable sport halls are addressed by subindicators on the basis of selected examples. The gap of a holistic assessment methodology for the sustainability performance of sports facilities does not exist anymore.

Additionally, the results were successfully applied on a real case (‘Am Sportpark’, Zorneding). Not only because of the innovative design and energy concept, but also by the integrated planning process which involved the later users as well as environmental friendly material selection and many more, the sports hall constitutes a flagship project on sustainable building.

An application of the developed method in practice is no more obstacles. So far, the methodology can be applied for stadiums and sports halls, but additional developments e.g. for swimming pools are conceivable. Further assessments in the way of case studies are recommended to proof the benchmarks.

5. Acknowledgements

The authors gratefully acknowledge the support of all members of the working group ‘AG Sportstätten’ whose efforts have profoundly affected the current work.

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Assessment of Land Use/Cover Change and Urban Expansion in Tehran, Iran, by using GIS and remote sensing

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Summary

Urbanization is one the most widespread anthropogenic causes of the loss of arable land, habitat destruction, and the decline in natural vegetation cover. Tehran as a mega city has been challenged by numerous difficulties like unplanned urbanization, traffic congestion, water logging etc. Geographic Information Systems and remote sensing are powerful and cost-effective tools for assessing the spatial and temporal dynamics of land use/cover changes (LULC). Remote sensing data provide valuable multi temporal data on the processes and patterns of LULC change, and GIS is useful for mapping and analyzing these patterns.

This study evaluates land use/cover changes and urban expansion in Tehran, Iran, between 1984 and 2014 using satellite images and socio-physical data. Spatial and temporal dynamics of LULC changes were quantified using four Landsat images, a supervised classification algorithm and the post-classification change detection technique.

The result shows that important growth of built-up areas in Tehran over the study period resulted significant decrease in the area of barren lands, cultivated land, and vegetation. Urban land expansion has been largely driven by population growth and elevation. The land use maps produced in this study will contribute to both for forecasting possible future changes in growth patterns and also the development of sustainable urban land use planning decisions.

Keywords: LCLU Land cover / Land use; urban growth; Tehran; Iran;

1. Introduction

Tehran is Iran's largest city and urban area, the largest city in Western Asia and one of the largest three cities in the Middle East (along with Istanbul and Cairo). According to DWUA [1], Tehran, the capital of Iran, is the twenty-second most populous city in the world with a population over 13.5 million people. Land cover and land use change (LCLUC) caused by urban growth is a global issue [2, 3] . Rapid changes in land cover / land use (LCLU) and increased environmental degradation in developing cities caused by population growth and human activities have enormous negative consequences. This LCLUC has resulted in a large loss of arable land to impervious land surfaces. In addition, it caused also the conversion of water areas, marsh areas, forest or grassland into built-up areas [4, 5]. With the growth of urbanization around the world, nowadays more than half of the world's population lives in urban regions, and

this trend is projected to continue in the future decades [2]. In order to decrease the detrimental effects associated with urban growth on the environment , the study of spatial and temporal LCLU patterns are considerably important for developing rational economic, social and environmental policies [6].
Geographical Information System (GIS), Remote Sensing (RS) provide powerful tools to study urban environments issues [2, 7-10] and urban growth modeling [11, 12]. Satellite remote sensing optical imagery provide valuable multi-temporal data on the processes and patterns of LCLU change, and GIS is useful for mapping and analyzing these patterns [13]. The integration of RS, GIS and spatial statistics provides a powerful and complementary suite of techniques for LCLUC monitoring and modeling. Spatial models can be more effective in modeling LCLUC, especially urban change and sprawl, when prior information about the spatial and temporal characteristics of urban development can be integrated [14]. A great number of change detection techniques have been developed to assess variations in LCLU by using satellite data [15, 16]. Of these techniques, the pre- and post-classification comparisons (PCC) have been extensively used (Singh 1989). The PCC examines changes over time between independently classified land cover data. Despite the difficulties associated with PCC, this technique is the most widely used for identifying LCLU changes [16, 17]. This technique is particularly useful for generating 'from–to' maps [17], which can be used to clarify the magnitude, location and nature of the identified changes [18].
The aim of this study is to explore the patterns of LCLU changes in Tehran .This will be done by integrating remote sensing-derived LCLU data and PCC algorithm.

2. Methodology

2.1 Study area

The study area is located in Tehran province (north of Iran), between 35°26'30"N / 51°43'39"E and 35°51'52"N / 50°58'36"E as shown in figure 2. The total area of this region is approximately of 321592 ha. This study area presents a surface elevation ranging from 930 to 3314 meters.

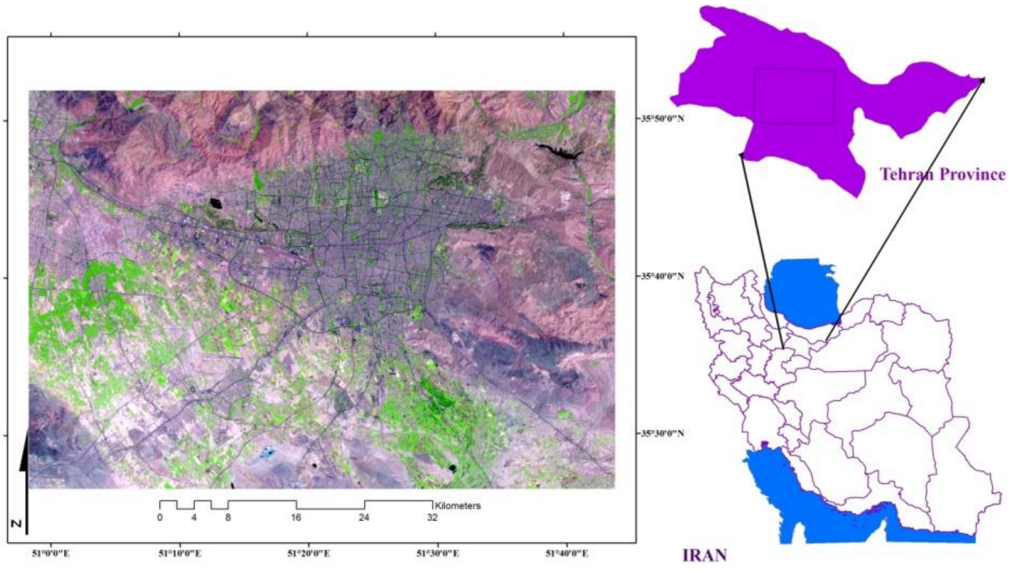


Fig. 2 Location of study area

2.2 Data

Table 1 provides detailed information on all datasets used in this study. Landsat TM (1984, 1994) and ETM+ (2004, 2014) satellite multispectral data were acquired and used to generate LCLU maps of study area for four separate dates.

Table 2 List and characterization of data used in this study

Type of data used	Scale/ Resolution	Source	Year
Landsat TM Image	30 M	USGS	8 July 1984
Landsat TM Image	30 M	USGS	18 July 1994
Landsat ETM+ Image	30 M	USGS	8 June 2004
Landsat ETM+ Image	30 M	USGS	11 July 2014
IKONOS Image	1 M	IKONOS Image (Google Earth-based)	April 2014
Topography	1: 25000	NCC	2010
Municipal boundary data	1:5000	Urban Development Office	2012
National Land use Dataset	1:2000	NCC and Urban Development Office	2000

*National Cartography Centre

2.3 Pre-processing Satellite Data

All images were geometrically registered and rectified using ground control points (GCPs) obtained from very high-resolution images and topographic surveys. The GCPs were dispersed throughout each image and the registration accuracy was less than 0.6 pixels. A second order polynomial fit was applied and images were resampled to 30 m output pixels using the nearest neighbor method. LCLU classes were typically mapped from digital remotely sensed data through the process of a supervised digital image classification. The Maximum Likelihood classifier (MLC) quantitatively evaluates both the variance and covariance of the category spectral response patterns when classifying an unknown pixel [19, 20]. In this study, four LCLU classes (‘Built-up area', ‘Water Bodies', ‘Greenland, and ‘Barrenland, Table 2) were established.

Table 3 LCLU classes used in the classification scheme

Land use/Land cover types	Description
Urban/built-up areas	Residential, Commercial and Services, Industrial, Transportation, Communication and Utilities, Roads.
Water bodies	River, Permanent open water, Lakes, Ponds and Reservoirs.
Greenland	Evergreen and Mixed Forest (natural and man-planted forests) and Cultivated land, Agricultural area.
Barren land	Bare soil/landfill sites, Area of thin soil, sand, or rock.

2.4 Classification accuracy assessment

A “confusion matrix” was used for assessing classification accuracy [21, 22]. Producer's accuracy (PA), user's accuracy (UA), overall accuracy (OA), and the Kappa statistic coefficient (Kappa) were determined as validation metrics in order to evaluate the performance of MLC classifier. (Table 3).

Table 4 Accuracy assessment of classification results for 1984, 1994, 2004 and 2014

		Built-	Water	Greenlan	Barrenland
1984					
UA%		82.9	99.03	99.03	98.04
PA%		86.41	99	94	91.9
OA%	91.84				
Kappa	0.8				
1994					
UA%		78.9	100	95.98	98.09
PA%		93.71	100	98.35	93.09
OA%	94.0				
Kappa	0.88				
2004					
UA%		98.01	100	99	94.69
PA%		96.42	98.97	99.78	97.08
OA%		96.92			
Kappa		0.94			
2014					
UA%		97.09	100	91.61	90.46
PA%		89.36	100	99.37	96.71
OA%	93.61				
Kappa	0.88				

2.5 LCLU change detection

In this study, post-classification change detection (PCC) technique was applied. This approach is effective for detecting the nature, rate and location of changes, and has been successfully used by a number of researchers in the urban environment [23, 24]. PCC is one of the most popular methods for change detection assessment. Post-classification comparison proved to be an effective technique, because data from two dates are separately classified, thereby minimizing the problem of normalizing for atmospheric and sensor differences between two dates. Cross-tabulation analysis was carried out to analyze the spatial distribution of different LCLU classes and changes [25, 26].Figure 2 summarizes the whole methodological approach that was applied in this study.

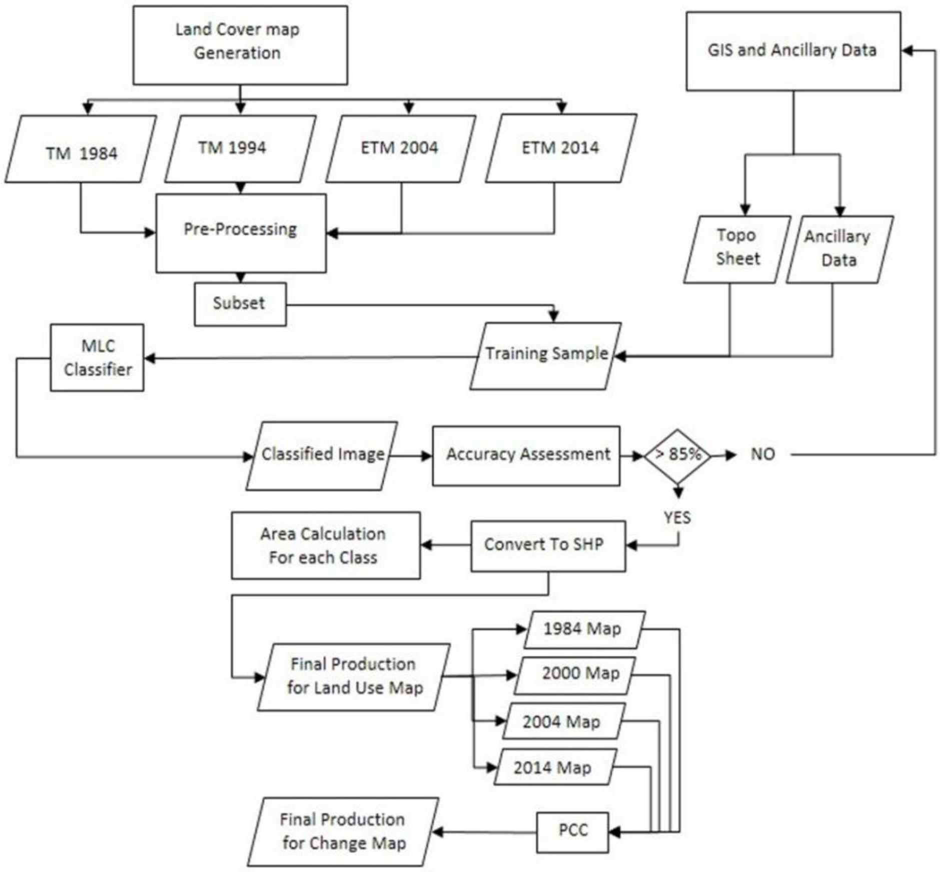
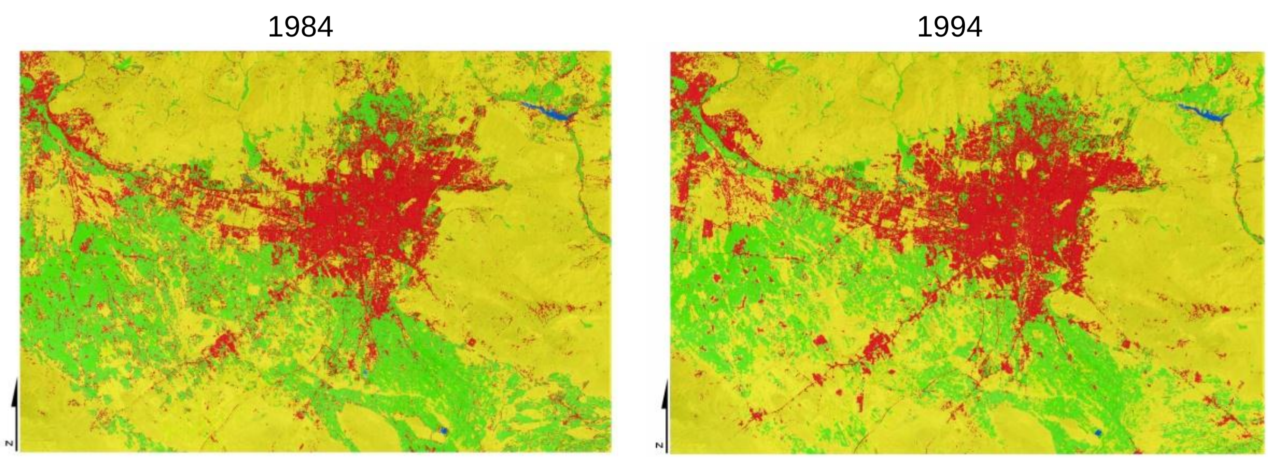


Fig. 3 Flow chart of overall procedures

3.Results and Discussion

Figure 4 shows the results derived from applying the maximum likelihood classification (MLC) algorithm. LCLU accuracy assessment showed an overall accuracy of 91.84%, 94.05%, 96.92%, 93.61% and kappa coefficient of 0.8, 0.88, 0.94, 0.88 for 1984, 1994, 2004 and 2014, respectively (Table 3).



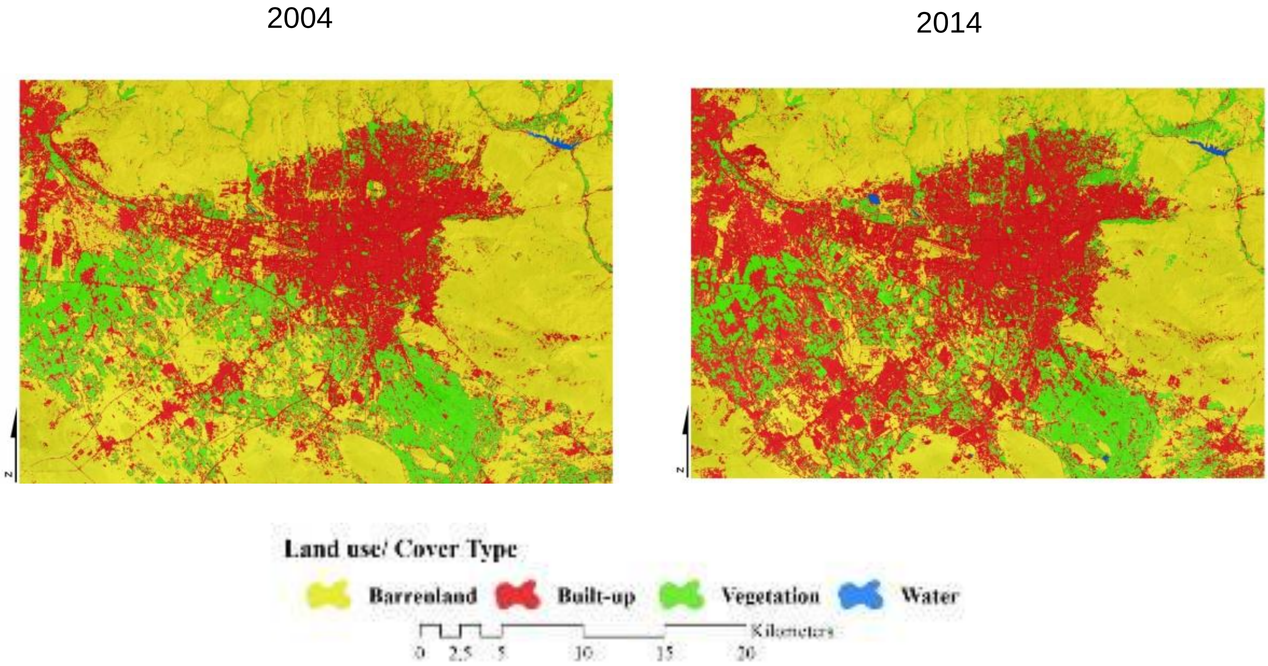
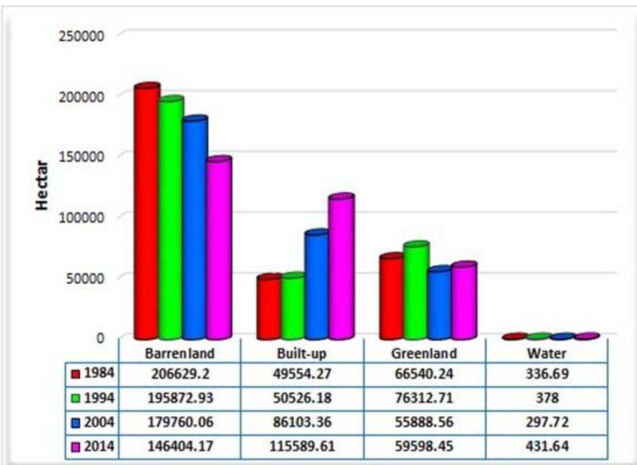


Fig. 4 LCLU maps

Figure 5 shows the area occupied by each LCLU regarding the total case-study area. Analysis of LCLU changes (Table 4) in study area revealed a considerable increase in the built-up areas over past 30 years. The built-up class was the most important LCLU type in the region. The built-up area increased from 49554ha to 50521ha from 1984 to 1994, from 50521ha to 86103ha from 1994 to 2004 and from 86103ha to 115589ha from 2004 to 2014. This figure demonstrates an annual urban growth rate of more than 2201ha per year.



	Barrenland	Built-up	Greenland	Water
1984	206629.2	49554.27	66540.24	336.69
1994	195872.93	50526.18	76312.71	378
2004	179760.06	86103.36	55888.56	297.72
2014	146404.17	115589.61	59598.45	431.64

Fig. 5 Total area of each land use /land cover 1984, 1994, 2004 and 2014

Table 5 Results of LCLU classification for 1984, 1994, 2004 and 2014; class percentage

LCLU	1984		1994		2004		2014	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (Ha)	%
built-up	49554	15.3	50521	15.6	86103	26.6	115589	35.7
Water	336	0.01	378	0.11	297	0.09	431	0.13
Greenland	66540	29.59	76311	23.6	55888	17.02	59598	18.4
Barrenland	206629	63.94	195900	60.62	179760	55.63	146404	45.3
Total	323111	100	323111	100	323111	100	323111	100

PCC change detection technique was used for identifying multi-temporal LCLU changes in study area from 1984 to 2014 Cross tabulation analysis on a pixel-by-pixel basis facilitated the determination of the quantity of conversions from a particular LCLU class to other LCLU categories and their corresponding area over the evaluated period. A new thematic layer containing different combinations of ‘‘from–to'' change classes was produced figure 6.

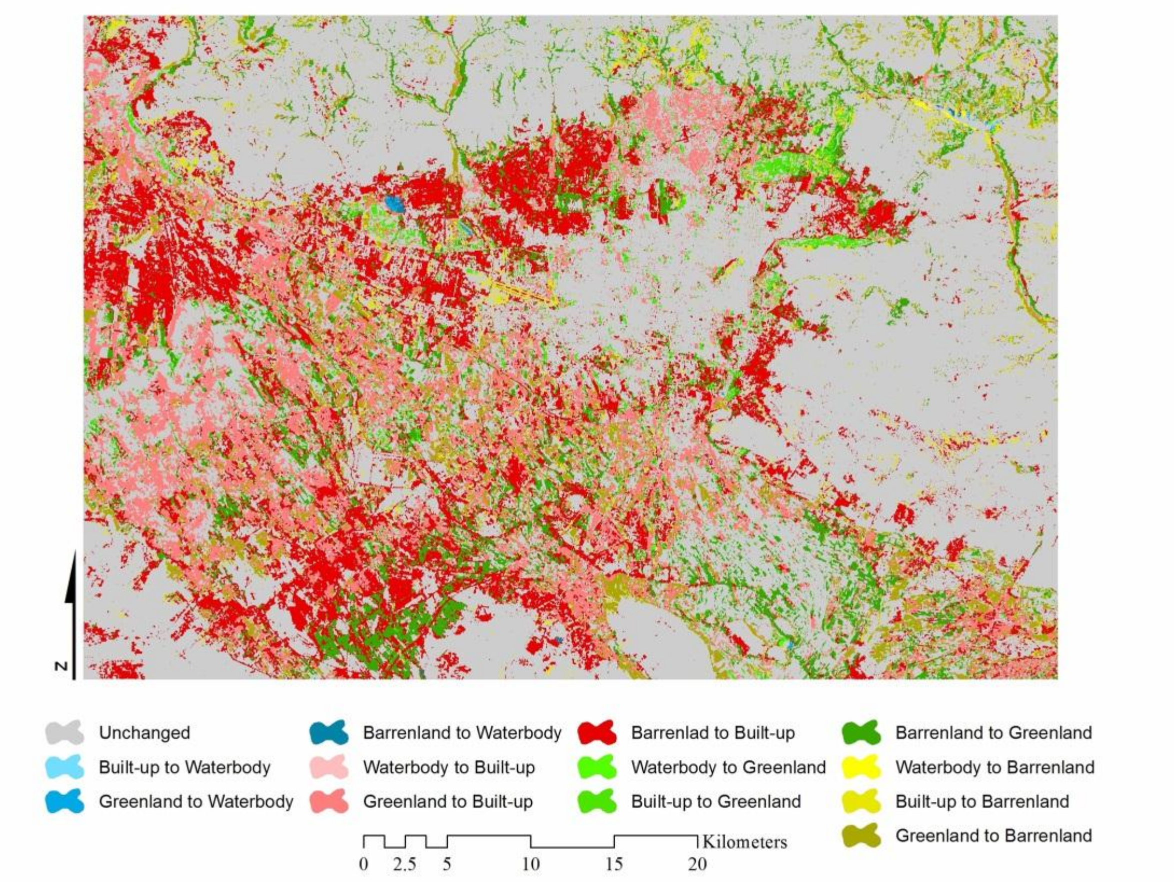


Fig. 6 LCLU conversions from 1984 to 2014

Table 6 shows a summary of the major LCLU conversions which occurred during the 1984-2014 period. According to this table, the majority of built-up area was acquired by converting areas that were previously ‘Barrenlands’, ‘and ‘Greenland' (about 48531.15ha and 31812.3ha respectively).

Table 6 LCLU conversions from 1984 to 2014

“From Class”	“To class”	1984-2014 Area (Hectare)
Built-up Area	Waterbody	50.22
	Greenland	7781.22
	Barrenland	7380.54
Barrenland	Built-up area	48531.15
	Greenland	21014.46
	Waterbody	118.53
Greenland	Built-up Area	31812.3
	Barrenland	13499.64
	Waterbody	89.37
Waterbody	Built-up area	58.23
	Barrenland	92.07
	Greenland	54.9

4. Conclusion

This study evaluating LCLU changes of Tehran by these steps .: (1) LCLU mapping through multispectral imagery supervised classification for 1984, 1994, 2004 and 2014; (2) change detection of LCLU from 1984 to 2014; The first procedure allowed mapping LCLU in the study area for 1984, 1994, 2004 and 2014. It has also enabled us to quantitatively assess the LCLU spatial distribution in each one of these years. Second procedure has allowed identifying and assessing LCLU changes during this 30 years period. This way, the magnitude, location and nature of the changes is able to be studied and assessed.

Cities act as a driving force for national and regional growth, create different attractions and opportunities for residents, in most of megacities into city immigration rate is positive and this cause some important challenges in sustainable development. Urban metabolism has a positive correlation with population and urban sprawl a big creature consume lots of sources and energies and exorcise waste materials and produce a huge amount of pollutants.

Tehran as a mega city has faced such problems. High rate of immigration in a wide range of reasons such as inequality facilities , job opportunities, education attractions and some events like war, droughts and it's impacts on agriculture and industries in other parts of the country. A large part of this new comers have settled in suburbs and slums. Lots of their constructions are illegal and informal. So Tehran has faced an unwelcome and unplanned expansion. Population force of finding a home cause destruction of green areas. Mentioning such causes, leads this paper to the structure of unplanned sprawl challenge of Tehran.

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Assessment of sensing performance of wireless illuminance sensors in built environment

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Summary

To attain intelligent control, the control algorithm needs to be fed with real time environmental data. Real time data, which comes from various sensors that act like “eyes and ears” of the system, directly impact the performance of the control system. This real time data, if not accurate enough, will cause a “garbage-in, garbage-out effect” that can negatively impact any control system. In this paper, a series of different combinations of natural (emulated) and artificial lighting conditions in the tropics are set up and measured. Data from the proposed high performance sensing platform is compared with GOSSEN professional handheld lux meter to show good agreement. In addition, 3D illuminance profiling of a space is displayed to show how reliable illuminance representation can allow occupants to efficiently appreciate and control the lighting conditions of their space.

Keywords: Wireless sensor network, illuminance sensor.

1. Introduction

Modern Building Management Systems (BMS) increase efficiency of energy use by employing both active and passive strategies [1]. Passive techniques include installing light shelves to bring in outdoor natural sunlight deeper into the building space, double glazing of glass to reduce heat transfer from outdoors to indoors, and stack ventilation to naturally bring in cooler air from outdoors [2]. Active techniques include having intelligent lighting controls together with sensors to optimise lighting usage in a building, using active chilled beams instead of chilled ceilings to provide higher convection efficiency, and active solar heating of water using flat plat collectors [3].

In Singapore, second to the industry sector, building sector consumes more than 30% of Singapore’s electricity, in which 20% is spent on lighting. As such, there is a huge incentive to optimise energy management for lighting loads in a building. In this paper, the focus would be on active technique of using high accuracy sensors with high-resolution platform for intelligent lighting control to assist BMS in making lumianires control more efficiently.

In modern day BMS, the control system has far reaching capabilities to control the usage of energy supplying to all electrical and electronics devices and equipment in a building [4], [5]. To attain intelligent control, the algorithm needs to be fed with real time environmental data. Real time data, which comes from various sensors that act like “eyes and ears” of the system, directly impact the performance of the control. This real time data, acts, if not accurate enough, will cause a “garbage-in, garbage-out effect” that can affect the occupants negatively.

In the field of artificial lighting in a building, the lighting control system needs to achieve two results concurrently. The lighting control system needs to sense the lighting condition in its surroundings, and adjust the intensity of the luminaires to optimally regulate the amount of power consumed. At the same time, visual comfort needs to be ensured so as not to compromise the health and productivity of the occupants. This is difficult to achieve with current standard light sensors with an error as poor as 40%. In order not to cause unnecessary frequent adjustments, which may cause discomfort [5], many control systems, taking into account such errors of light sensors, will stop lighting control with a large upper and lower bound of the set illuminance.

For human visual comfort in the office, occupants typically would not notice much difference if the illuminance varies by 50 to 100 lux. This means that the entire lighting system would need to have an error of less than 10%. It is therefore necessary to deploy sensors that have such accuracies to effectively achieve optimal energy usage and occupant visual comfort.

Light sensors that can fulfil such accuracies (3% to 7% error) are typically handheld luxmeters such as from Gossen [6], and expensive and bulky photo sensors. Recently, there has been a trend by various manufacturers to produce small form factor, but still highly accurate sensors. One such type of sensor is from EKO Instruments [7], which has a range of small sensors for portability and at the same time, having a much lower cost than professional handheld luxmeters.

Therefore, this paper proposes an alternative method of integration that is easy to design, low power for battery operation, portable for easy deployment, wireless Zigbee for ease of integration with BMS, and highly accurate with high resolution data output for precise control of lighting to achieve effective energy management without compromising human visual comfort.

2. Methodology

2.1 Objectives of high accuracy illuminance sensors

Table 1: Comparison of low cost sensors

Types	Operation	Advantages	Disadvantages
Digital chip sensors	I^2C or SPI interface	Ease of integration Low cost Very small size	Low accuracy of > 15% error
Analog chip sensors	ADC required	Low cost Very small size	Low accuracy of > 15% error
Photodiode	ADC required	Very low cost Very small size	Low accuracy of > 35% error
Digital chip sensors	I^2C or SPI interface	Ease of integration Low cost Very small size	Low accuracy of > 15% error

Table 1 shows a summary of the three main types of illuminance sensors that are readily available in the market. They are digital chip type sensors, analog chip type sensors, and photodiode. Photodiode being the cheapest of the three types of sensors, provides the largest error. This type of sensor is typically good for detection of the presence or absence of light in the environment.

Taking a basic control algorithm as shown in Fig. 1 as an example. This algorithm does not have any many intelligent build in. It is a region based decision making algorithm where a search criteria on the set range determines the result. Table 2 shows the descriptions of the variables used in the flow chart. Using this algorithm as a basis of comparison, three types of sensors with three different types of accuracies, 3%, 15%, and 35% are simulated. Table 3 shows the values of the variables used in this simulation. The set illuminance value is 400 lux, which is halfway between the recommended 300 lux to 500 lux for an office work plan environment [8]. A certain luminaire is also taken to be dimmable with a range of 400 to 500 lux for this simulation. This is to keep the simualtion within a pracitcal and manageable limit. The step size per dimming adjustment is set at 5%, and that if the sensor collects illuminance readings of within 5% of the set value, further adjustments would be stopped.

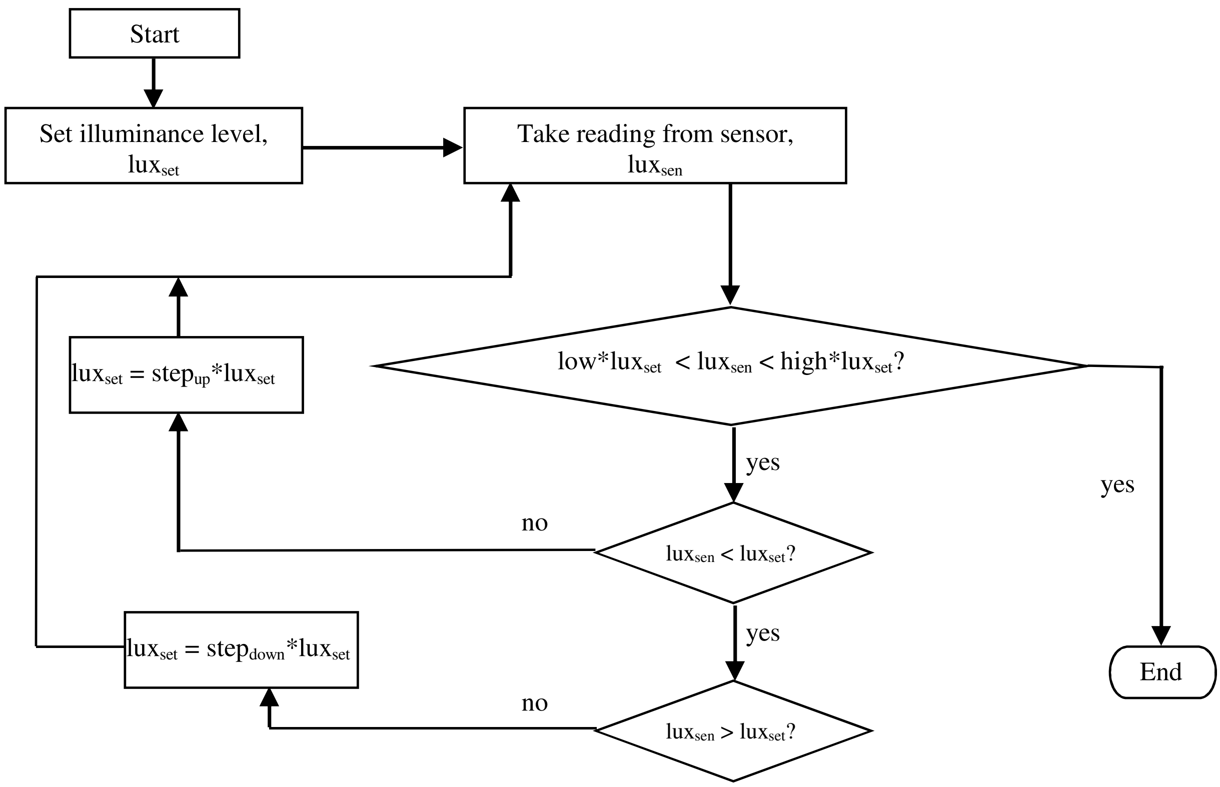


Fig. 1 Basic lighting control flowchart

Table 2: Description of variables

Variable	Description
lux_{set}	Set illuminance level
lux_{sen}	Sensed illuminance level by sensor
$step_{up}$	Step size increase of illuminance level of luminaire
$step_{down}$	Step size decrease of illuminance level of luminaire
low	Lower bound of set illuminance level
high	Upper bound of set illuminance level

Table 3: Set values of variables

Variable	Values
lux_{set}	400 lux
Luminaire dimming range	400 lux to 500 lux
$step_{up}$	5 %
$step_{down}$	5 %
low	5 %
high	5 %
Sensor 35	Sensor with 35 % error
Sensor 15	Sensor with 15 % error
Sensor 3	Sensor with 3 % error

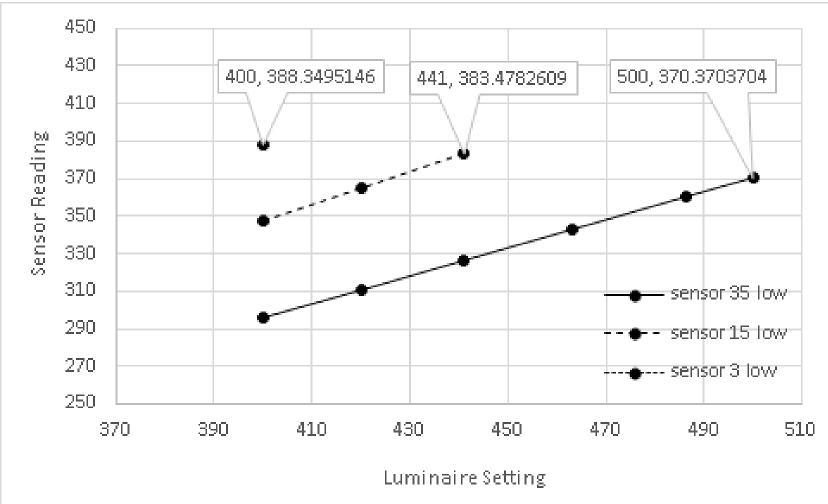


Fig. 2 Comparison of number of steps to lux_{set} for negative error of sensors

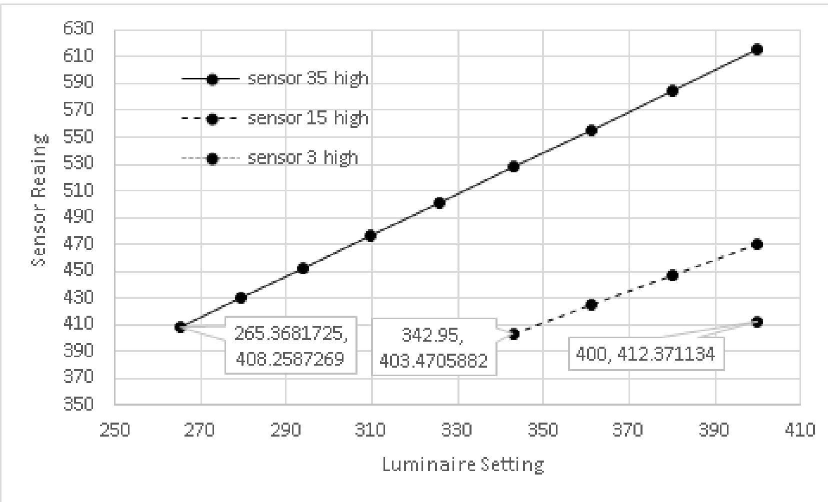


Fig. 3 Comparison of number of steps to lux_{set} for positive error of sensors

Fig. 2 shows the comparison of the three different types of errors when they experience negative errors. From the figure, it can be seen that the starting sensors readings are lower than their individual errors when the set illuminance level is 400 lux. In an ideal case, this would not cause any

2.2 Proposed high illuminance accuracy sensor

(a) (b) (c)

Fig. 4 Proposed EKO sensors

Table 4: Properties of EKO sensors

	ML-020S-I Indoor illuminance sensor	**ML-020S-O Outdoor illuminance sensor**	**ML-01 Irradiance sensor**
Measurement Range	0 - 30,000 lx	0 - 150,000 lx	0 - 2,000 W/m^2
Output Voltage	0 - 30 mV	0 - 30 mV	0 - 100 mV
Internal Resistance	1300 Ω	280 Ω	-
Error	2.3%	2.3%	< 2%

Fig. 4 shows the proposed high accuracy small form factor sensors from EKO Instruments. Their properties are shown in Table 4. As can be seen, the errors of these sensors are less than 3%. This is comparable to professional handheld lux meters which also have errors of less than 3% to 8%.To integrate these sensors, a high resolution ADC is proposed. The resolution of the ADC can affect the sensitivity of the sensors.

Table 5: Resolution versus sensitivity

Resolution	**3.3 V V_{ref} Sensitivity**	**5 V V_{ref} Sensitivity**
10	3.22 mV / level	4.88 mV / level
15	100.7 µV / level	152.6 µV / level
20	3.15 µV / level	4.77 µV / level
24	0.197 µV / level	0.298 µV / level

From Table 5, it can be seen that a 24-bit ADC provides the highest sensitivity giving a maximum of 0.197 µV per ADC level. This corresspnds to 0.197 lux per level for the indoor illuminance sensor, and 0.985 lux per level for the outdoor illuminance sensor. Thus, it can be seen that in order to have a sensitivity of 1 lux per level for a wide range illuminance sensor, a 24-bit ADC is needed.

Fig. 5 shows the proposed integration of the sensor, ADC, and microcontroller. As the system is running on 5 V, the entire platform can be power by rechargeable lithium-ion batteries, making it portable and light.

Fig. 6 shows the deployment of a grid of sensors in a testbed. The sensors with levelling plates are placed on the stands while the rest of the components are hidden inside the stands.

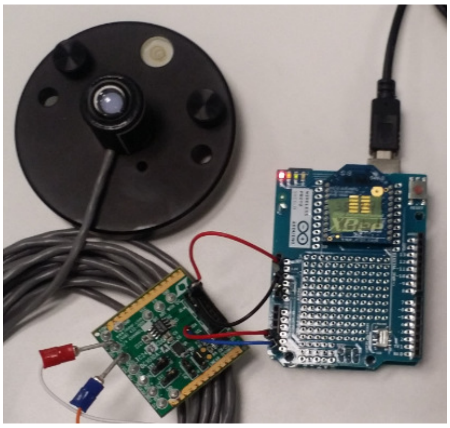


Fig. 5 Proposed integration of analog sensor, ADC, and microcontroller

3. Results

Fig. 6 Grid deployment in test bed

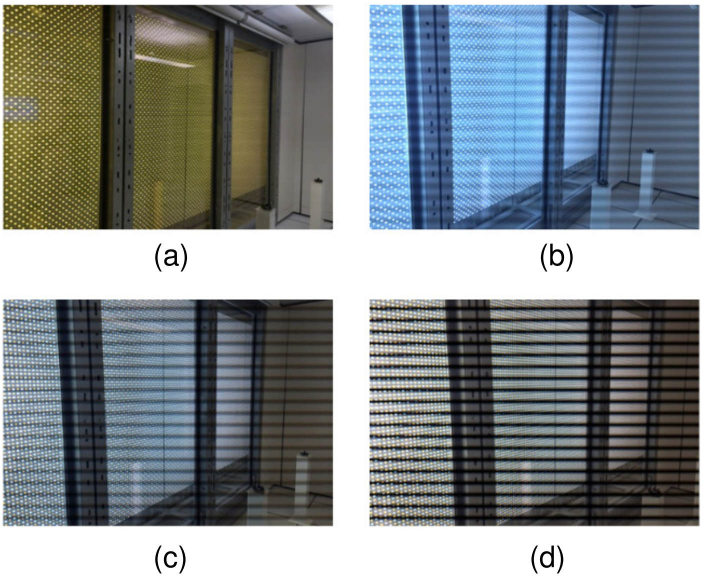


Fig. 7 Four scenes of diffused daylight tested (a) sunset/sunrise (b) blue sky (c) cloudy day (d) mid-day

Fig. 7 shows the four test scenarios that were emulated by the daylight emulator placed outside the test bed. Fig. 8 shows the data plotted based on the sensors data placed in the grid. The readings are linked together in the plot using spline interpolation.

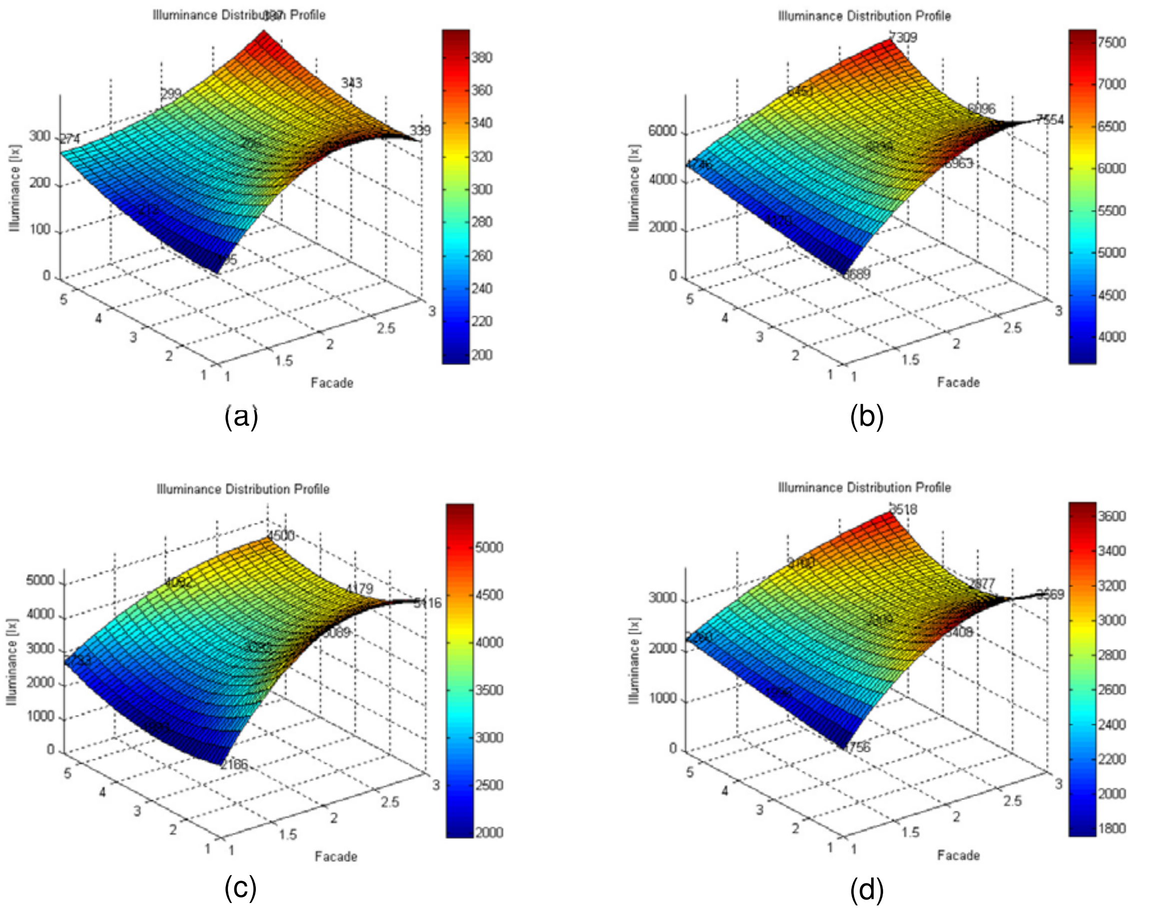
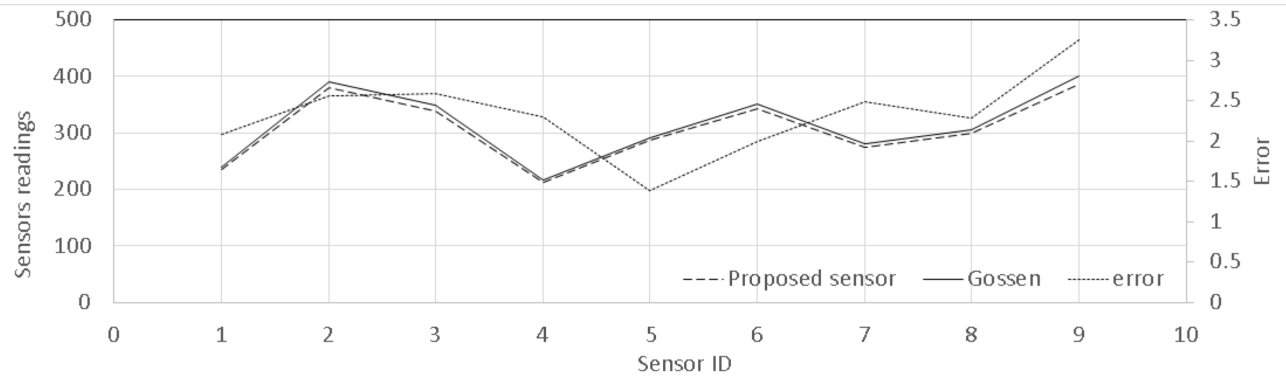


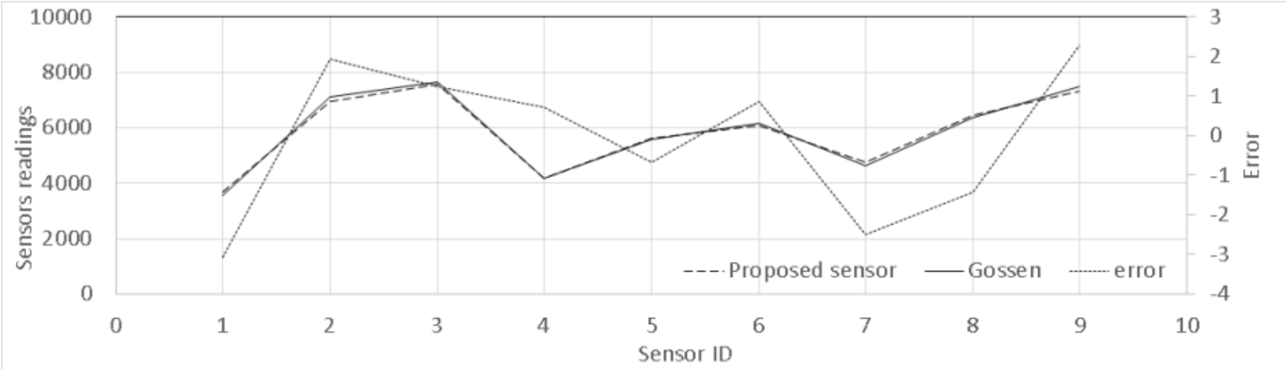
Fig. 8 Four illuminance profiles of (a) sunset/sunrise (b) blue sky (c) cloudy day (d) mid-day

To verify the accuracy of the sensor grid data, a manual measurement using GOSSEN lux meter is performed.

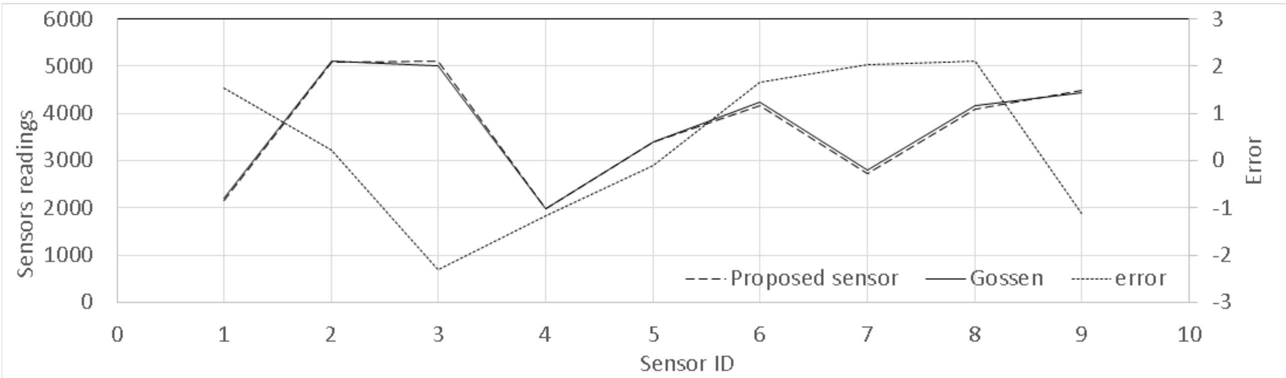
Fig. 9 show the measurement comparison between the proposed sensor grid measurements against the professional handheld lux meter. From the four scenarios, it can be seen that the maximum error between the two instruments is 3%.



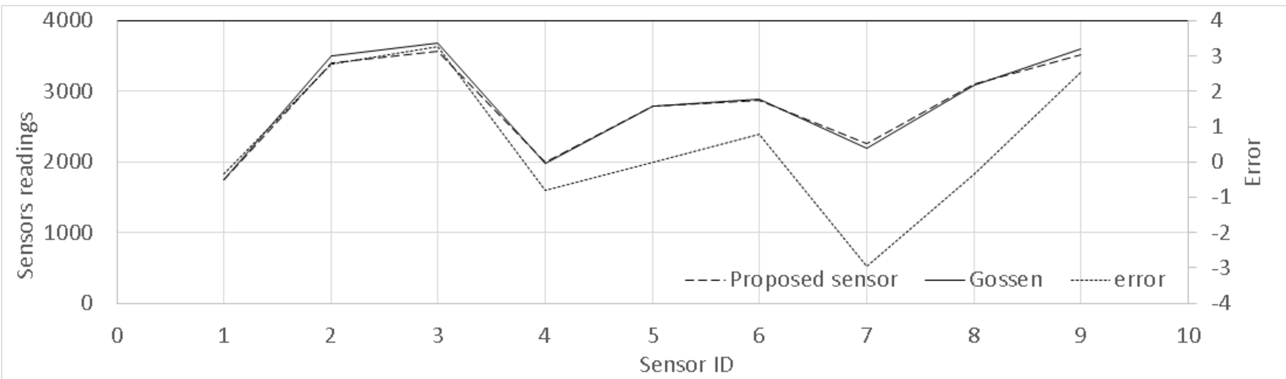
(a)



(b)



(c)



(d)

Fig. 9 Error plots of (a) sunset/sunrise (b) blue sky (c) cloudy day (d) mid-day

4. Conclusion

Simulated results show the need for high accuracy illuminance sensors in order to achieve visual comfort and energy savings. A method of integration of high accuracy illuminance sensors with a high resolution wireless platform is proposed. This proposed platform is tested in a grid under different conditions emulated in a test bed. The results from the sensors grid are verified with a professional handheld lux meter to show good agreement between the readings of less than 3% erros.

5. Acknowledgements

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Assessment of Walking Experience in Kitakyushu, Japan

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Summary

Various attributes addressing the issues on walking environment and walking condition possibly has distracted the efforts of creating better planning and development to promote walking to the citizen. It will take an enormous effort and time for them to consider all the attributes that are available. Therefore authors assess the possibilities of the utilization of the Pedestrian PL.AC.E. (Profile, Activity, and Environment) and its key-attributes using a survey questionnaire in order to confirm that it can serve as a framework for urban planning or assessment in promoting a walking-friendly environment. The questionnaire was distributed to the case study area which is the city of Kitakyushu, Japan. For this study authors distributed the questionnaire by collaborating with the first year students of the Department of Architecture, the University of Kitakyushu, Japan. After collecting and documenting all responses, the results were analyzed using descriptive type of statistical analysis with SPSS software.

By descriptive analysis, authors managed to conclude the profile of the pedestrian of which represented partly of the people who experience walking in Yahatanishi area. As for the pedestrian activity, author concluded that walking activity was conducted by the respondents in accordance with their daily activities in a form of short distance journeys. The walking activity was still influenced by concerns regarding safety from traffic (cyclist) and crime especially during night time. Authors noticed also that the use of smartphone could be utilized to improve walking experience in the future. In regard to the Pedestrian Environment, there were positive evaluations of the physical condition of the pedestrian facilities. However in relation to the quality, the positive responses were decreased. These results confirmed that self-assessment method using questionnaire and statistical analysis could utilize key-elements and key-attributes to plan or evaluate, and regenerate a sustainable and local-based model of walking environment. However authors were also convinced that the framework should be further tested on more representative targets and should be analyzed with different type of statistical analysis for more comprehensive interpretation.

Keywords: walking, pedestrian profile, walking environment, assessment, walkable city

1. Introduction

The developments toward the promotion of walking in urban area that focused only on improving the walking environment often fail to encourage people to walk. Thus one needs also to elaborate and address the factors of walking condition. Many studies from various disciplines were already conducted to define the attributes of walking condition that could be improved. So then the main question for this research is how to create a cross-field framework consisting common key-attributes of walking to serve as a measure for urban planning or assessment. Authors acknowledge that the attributes were the outcomes of multi-disciplinary researches, thus authors focus on subjects that are related to urban planning.

Prior to this study authors already conducted extensive literature reviews of scientific journals and papers as reported in author`s previous paper [1]. The manuscripts were collected and then a content analysis was conducted to extract all keywords, generate groups of key-elements from the keywords and later to synthesize common attributes in the current study of walking. There were in total 111 keywords with many of them were repeated from one manuscript to another, have similar meaning and terminology, or are related to each other. Keyword is considered as a very short point of summary of the manuscript from which reader could understand the main topic. Therefore after grouping the keywords, authors concluded that in order to discuss and elaborate the walking phenomenon there are key-elements of Pedestrian Profile, Pedestrian Activity, and Pedestrian Environment which are being introduced by authors as its abbreviation, PL.AC.E. (ProfiLe, ACtivity, Environment).

Authors continued further content analysis by extracting research key-attributes from the manuscripts. The key-attributes are various parameters, factors, or measurements which were being discussed, elaborated, and studied within each referenced manuscripts. Then the key-attributes were categorized based on the key-elements of PL.AC.E. Authors proposed that the key-element of Pedestrian Profile could be defined by key-attributes as follow: age; financial income; physical condition; gender; mobility choice; employment and education background; social cultural capital; pedestrian type; and public transportation usage. Authors further proposed that the key-element of Pedestrian Activity could be defined by key-attributes as follow: walking-related purposes; social interaction; walking intensity; walking habits; and transport modes interaction. The last is the key element of Pedestrian Environment of which could be defined by key-attributes as follow: spatial planning; walk-ability; neighborhood livability; traffic safety; pedestrian facilities (hard elements); pedestrian facilities (soft elements); and environmental quality

By contextually defining and/or re-defining the PL.AC.E., authors suggest that an urban area could be assessed for its existing performances and/or be improved based on its potentials to become a walk-able area. However it is required to examine and to find the best method to utilize this framework. Therefore in this paper, authors assess the possibilities of the utilization of the PL.AC.E. and its key-attributes using a survey questionnaire which is the most used method in the study of walking phenomenon. The purpose is to confirm that it can serve as a measure for urban planning or assessment in promoting a walking-friendly environment. The framework should be able to identify the propensity of each key-attribute in order to understand the characteristic of research subject. The framework also should be able to elaborate the relationship between the key-attributes within each key-element in order to find unique phenomena related to walking. The propensity and the relationship will be valuable information for planning and assessment process.

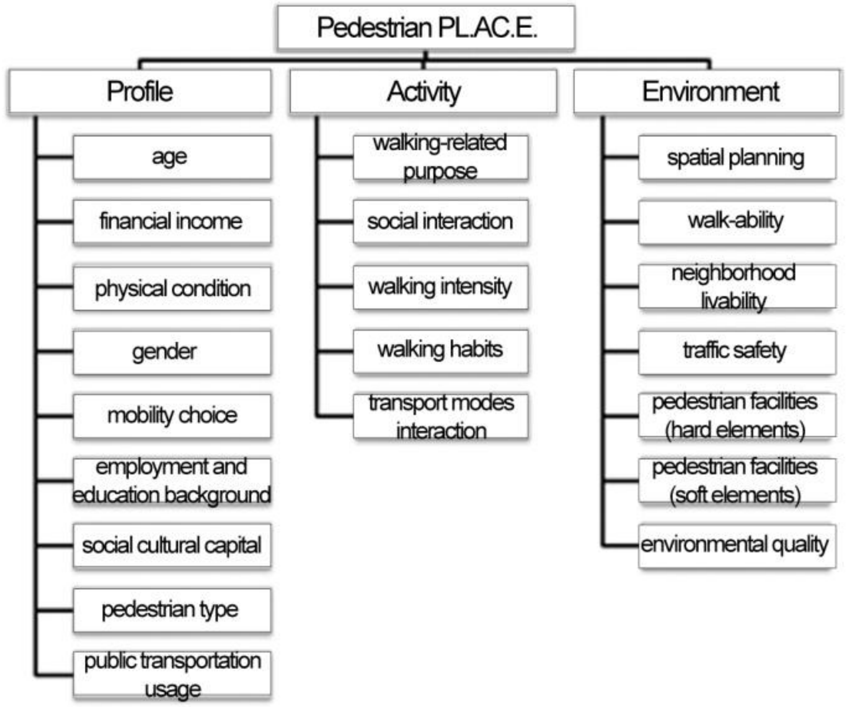

Fig. 1 Diagram of PL.AC.E and its Key-atributes

2. Methodology

2.1 Data colletion using Questionnaire

The method of data collection using questionnaire was selected based on the finding that this is the most common method for data collection in the study of walking phenomenon. The questionnaire was designed to target different kind of respondents and areas so then the result could be representing different scenarios for the validation process. Mainly there were three methods of questionnaire distribution which were distribution in a group at certain time and place, in-directly through third parties, and on street survey. For both in-direct and on-street distribution, return envelopes were provided so that the respondents could send back the filled questionnaires by post without any cost since the envelopes were already registered and stamped.

The questionnaire was prepared based on the key-elements of Pedestrian PL.AC.E. and its key-attributes. Authors generated 3 parts with total of 68 questions written in Japanese. Part 1 was consisted of 15 questions reflecting key-attributes to understand Pedestrian Profile. The questions were designed as categorical type questions with contents of as follow: public transportation usage; transport mode to work, school, daily market, public facilities, and for recreation; car ownership and usage; motorbike ownership and usage; familiar with the term “Climate Change”, “Greenhouse Gases (GHG) or CO2 Emission”, and “Low Carbon Principles or Low Carbon City”; type of living place; reason choosing living place; period of living; and physical activity. Several key-attributes related to respondent’s identities were asked separately prior to this part within 8 questions which are: employment status; current address; place of work/school; marriage and number of household member; age; gender; hometown; and nationality.

Part 2 was consisted of 25 categorical type questions reflecting key-attributes of Pedestrian Activity as follow: frequent walking location; walking duration; walking purpose; accident with bicycle, car/motorcycle; transports combination; public facilities availability; walking in daytime, night time; walking regularity; walking activity when alone; walking and travel cost; visual attractors; crosswalk attitude; walking route familiarity; common walkway description; favorite walkway part; reason for choosing walking area; walking position adjustment; and interaction with other pedestrians.

And part 3 was consisted of 20 ordinal type questions reflecting key-attributes of Pedestrian Environment with contents of as follow: seating place or rest area; pedestrian crossing/bridge; quality of noise environment; street lighting; pedestrian warning/guidance signage; safety (from traffic); security (from crime); access to open spaces or parks; feeling when walking; width of sidewalk; walkway physical condition; greeneries along the sidewalk; walking comfort; cleanliness; access to public transport; pavement; land-use diversity; accessibility for disable person; route network or connectivity; attractiveness of visual P.O.I. (Point of Interest); aesthetic; general weather condition in summer; general weather condition in winter; population/neighborhood density; and distance to destinations.

2.2 Dataset I: The Students

Following the finalization of the questionnaire, authors conducted the first experiment to assess the questionnaire. The respondents were the first year students of the Department of Architecture, the University of Kitakyushu, Japan. The distribution was conducted on April 28th, 2015 between 9.15 A.M. until 9.45 A.M. at the CAD Room of the Department of Architecture, the University of Kitakyushu. 61 sets of questionnaire print-out were prepared based on the number of course participant and distributed to the students. Authors gave brief explanation about the research purposes prior to distribution. Afterward only 58 questionnaires were returned.

2.3 Dataset II: The Typical Families

After the distribution of the questionnaire to the students, authors tried to collect the research dataset from another group of respondents. The typical young nuclear Japanese families were targeted as the respondents which are families generally consisting of working husband/father as head of the household, housewife/mother, and children (mostly at early age) living together in one household. The reason of choosing these families was because author would argue that essentially they could play important role to solve the decreasing population of Japan.

As for the above background, the data collection was conducted in collaboration with the local kindergarten which is Asakawa Youchien. This kindergarten is located within the ward of Yahatanishi, Kitakyushu as the case study area. Prior to the distribution of the questionnaire, the headmaster was contacted in order to get approval and permission. The questionnaire was agreed to be distributed to the parents of the kindergarten pupils of the last (third) grade. The teachers were explained about the questionnaire and 200 sets of the questionnaire were distributed through the children. The distribution was conducted on May 25th, 2015 on each class of the third graders. The deadline of a week later was set up and post paid registered return envelopes were provided. After the deadline, 43.5% (89 sets) of the questionnaire were returned.

2.4 Dataset III: The Urban Commuters

To complement and create variation of inputs to the datasets, the questionnaire was also distributed to the last group which is labeled as The Urban Commuter. This group consists of different types of respondents of which based on direct observation are often found to be walking in the case study area. They are the elderly or senior aged people, the joggers or people who walk with their pet, and then the public transport users. There were 2 methods of distribution, firstly by distributing to their mailboxes and secondly by on-street distribution. For type A, the senior aged people, self-administered questionnaire sets with return envelope were distributed into the respondent's mailboxes in a residential area located at Kifunedai and Honjohigashi, in Yahatanishi. Meanwhile for type B and type C, the joggers and the people on street, the questionnaires were distributed the questionnaire first hand or directly along the jogging track in Hibikino and along the sidewalk at Gakuen Odori towards the Orio Station. The respondents were given one week to answer and return the questionnaire by post. The deadline was June, 15th 2015. In total there were 120 sets of questionnaire distributed and 43 sets were returned. For a complete overview of the dataset III and also the other datasets, please refer to Table 1.

Table 1: Overview of data collection

Nr	Respondents	Method	Period	Place	Distributed	Returned	%
I	The students of the University of Kitakyushu	In-place group administration of printed questionnaire was conducted at a designated time and place.	1 hour (April 28th, 2015)	CAD Room, S Building, Hibikino Campus, the University of Kitakyushu	61 sets	58 sets	95
II	The parents of the Asakawa Kindergarten pupils	Self-administered questionnaire sets with return envelope were distributed through the pupils within each class.	1 week (deadline by June 1st, 2015)	Asakawa Kindergarten in Fujiwara, in Yahatanishi	200 sets	89 sets	43.5
III	The urban commuters A: The elderly or senior aged people	Self-administered questionnaire sets with return envelope were distributed into the respondent's mailboxes in a residential area.	1 week (deadline by June 15th, 2015)	Respondent's houses in Kifunedai and Honjohigashi, in Yahatanishi	70 sets	12 sets	17.1
	The urban commuters B: The joggers and people who walk their pet	Self-administered questionnaire sets with return registered envelope were distributed directly to the respondents on street in a jogging track and the surrounding residential area.	1 week	Hibikino area and the surrounding.	20	17 sets	85
	The urban commuters C: The people on street	Self-administered questionnaire sets with return registered envelope were distributed directly to the respondents on street along the sidewalk.	1 week	Gakuen Odori street toward Orio station	30	14 sets	46.7
	TOTAL				381	190	49.7

3. Analysis and Results

In order to comprehend and discuss the result of the data collection, series of statistical analysis were conducted using the SPSS (Statistical Package for Social Sciences) software version 17. After inputting the responses, authors started data analysis by conducting a descriptive statistical analysis using frequency procedure. The purpose was to identify the propensity of each key-attribute in order to understand the characteristic of research subject.

3.1 Pedestrian Profile

From the analysis using frequency procedure it can be concluded that the common attributes from all 3 datasets are that they are not daily-based public transportation users, as seen from Figure 2, they are/were studying and/or working in the city of Kitakyushu, their level of knowledge towards environmental terms were very low, they lives in Kitakyushu city currently especially in the case study area which is in the ward of Yahatanishi.

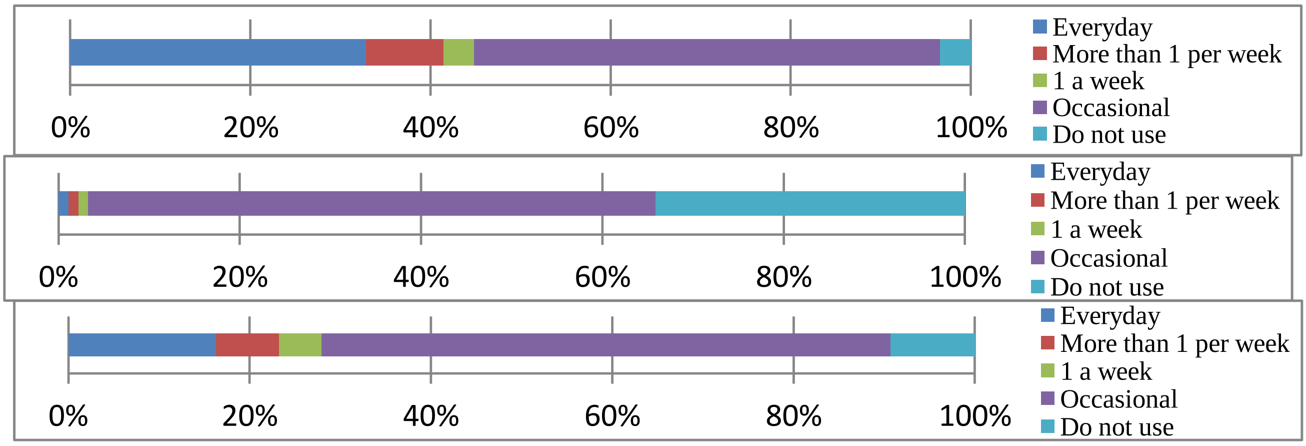

Fig. 2 Percentage of public transportation usage of: Dataset I (top); Dataset II (middle), and Dataset III (bottom)

3.2 Pedestrian Activity

The propensity of the frequent walking location from all 3 datasets indicated that people are walking around their neighborhood despite of lesser percentage from Dataset I. And also walking in the day time was still more preferable than in the night time because of the safety reason. Because safety was not just from crime but also from traffic since it was found that there were conflicts between pedestrian with car/motorbike and also with bicycle of which the later became the most reported. All 3 datasets represent similar common walkway description which is walkway with greeneries. However the small percentage indicated that the responses were heterogeneous.

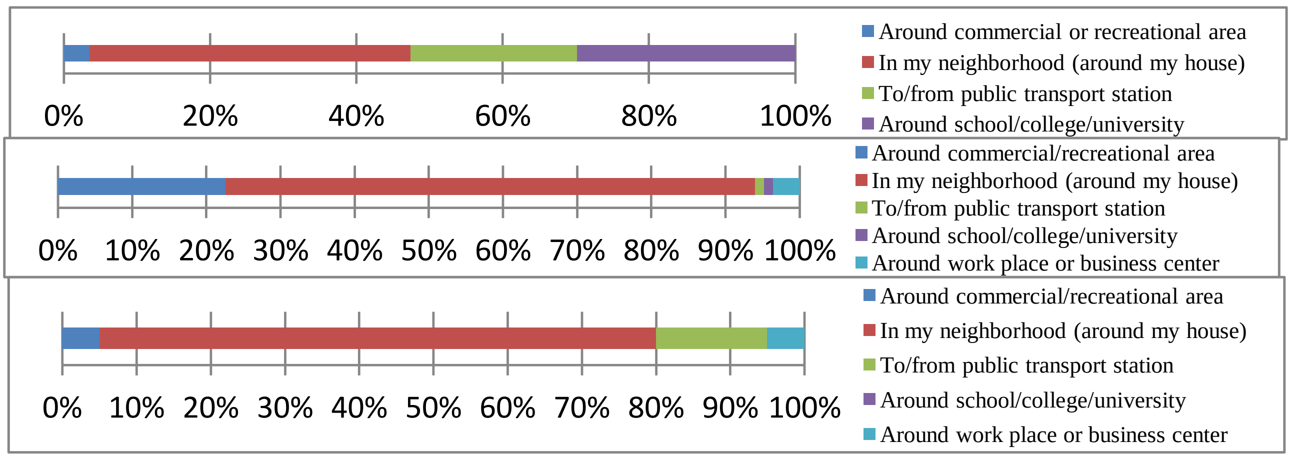

Fig. 3 Percentage of frequent walking location of: Dataset I (top); Dataset II (middle), and Dataset III (bottom)

3.3 Pedestrian Environment

Based on the frequency analysis of the pedestrian environment, there are indications of uncertainty or dissatisfaction for factor such as seating places or rest areas, safety (from traffic), quality of noise environment, population/neighborhood density, accessibility for disable person, general weather condition, aesthetic, and land-use diversity. However these are only possibilities since the dissatisfaction was never mentioned clearly instead only by stating "so-so" of which could also represent uncertainty as the result of inexperience profile. On the contrary only the route network or connectivity was appreciated.

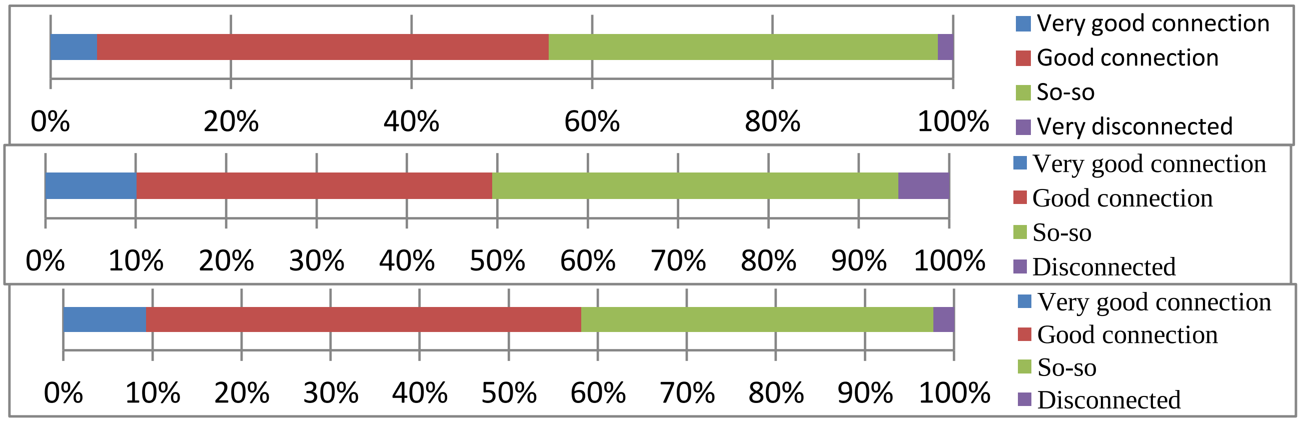

Fig. 4 Percentage of route network or connectivity of: Dataset I (top); Dataset II (middle), and Dataset III (bottom)

3.4 Total Result

The propensity of each key-attribute for each dataset was assessed. The answer reaching a percentage of 50% or higher was considered to likely represent a trend or propensity since it showed the homogenous of the answers. Yet the answer with a percentage lower than 50% was considered to fairly represent a trend or propensity since it showed more various answers. However for this assumption, the missing responses could not be over 5% for each question.

For the key-attributes of Pedestrian Profile, most of the answers showed the propensity of each dataset since the dataset was representing a group of people such as students and parents (mostly the mothers). Only Dataset 3 had rather slightly more answers with a percentage lower than 50% since it was more random group compared to the other two. For the key-attributes of Pedestrian Activity, Dataset 1 had rather more responses with a percentage lower than 50% compare to the other datasets presumably because their active and various living style. Based on the propensity reading of the pedestrian environment, there are indications of uncertainty or dissatisfaction for factor such as seating places or rest areas, safety (from traffic), quality of noise environment, population/neighborhood density, accessibility for disable person, general weather condition, aesthetic, and land-use diversity. However these are only possibilities since the dissatisfaction was never mentioned clearly instead only by stating "so-so" of which could also represent uncertainty as the result of inexperience profile.

4. Conclusion

The data analysis using frequency procedure towards the key-attributes of Pedestrian Profile was proven to be able to identify the profile of certain people especially in regard with their walking performance. By doing this analysis we could define whether one group represents the profile of pedestrian or not and of which kind. From the datasets we could understand that the students do walk indeed yet it is the second choice after cycling and less related to the environmentally friendliness. Meanwhile the housewives are highly dependent on the use of cars. The group of urban commuters showed an indication that they indeed use public transportation for daily purpose such as work. Furthermore they combine it with walking.

This study was focused toward walking experience within the ward of Yahatanishi of Kitakyushu city. However authors identified that most of the respondents lived in Yahatanishi. The propensity of the frequent walking location from all 3 datasets indicated that people are walking around their neighborhood. Thus the respondents profile represented the people who experience walking in Yahatanishi. Based on this finding, it is recommended that the priority and focus of developing a walkable area should be given towards the residential area especially within the homogenous land-use development.

				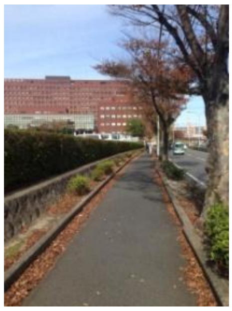
roadside (no barrier/sign)	roadside (only divided by colour/line mark)	narrow sidewalk	sidewalk with no greeneries	sidewalk with greeneries

Fig. 5 Sidewalk types in Yahatanishi

However Dataset 3 had rather slightly more answers with a percentage lower than 50% since it was more random group compared to the other two meaning that we hardly could understand the profile. Therefore this tool requires a designated group of people rather than random sample. It could be based on the neighborhood (the environment) or the social cultural setting (the activities). General sampling will result general reading of which could not assess specific issue on specific area within specific group of people.

By synthesizing key-elements and key-attributes from literatures studies, a tool for comprehensive planning and assessment was proposed so that an urban area could be assessed for its existing performances and/or be improved based on its potentials to become a walk-able area. The tool was able to identify the propensity of each key-attribute in order to understand the characteristic of research subject.

5. Acknowledgements

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benefit E, Strategies for building integrated solaractive systems

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Summary

Funded by the ZukunftBau research initiative the research project examines existing barriers to building integrated applications of solar-active systems. In addition to identified barriers, strategies to expand the margin of composed usage of solar active systems in the building shell are pointed out. The research project benefit E shows the possibilities of using solar active systems as architectual element in the building envelope in context of existing legal, technical and economic conditions. The practically orientated final report provides suggestions for planners, builders and companies equally to minimize costs, early detecting possible risks in implementing active systems in the building shell and further technologies developments.

Keywords: building integration, solaractive systems, building-related energy production, designing building shell

1. Introduction

Energy demand and energy supply in Germany
According to the preliminary data of the Federal Statistical Office, the final energy demand in Germany in 2013 was approximately 2,578 TWh/a. The electrical energy demand was around 529 TWh/a; 20% of the overall demand. A total of 23,4% of the electrical energy was produced through photovoltaic, hydropower and biomass. The heat demand (spatial heating, warm water, process heat) was 1489 TWh/a; 58% of the overall demand. Looking at the entire ‚energy picture‘, the total proportion of electrical and thermal energy generated from renewable energy sources lies only at 7% which is far too low when considering a long-term CO2-neutral development.

To implement a new energy policy, it is necessary to accelerate the production of solar, wind, biomass, and geothermal energy quickly. In terms of power supply, energy storage needs to be developed on top of expanding the supply networks. The current energy supply structure is composed of a central power supply where the energy is then transported through networks to the end user. As part of the increased use of renewable electricity, the system must convert to a decentralized power supply. At the beginning of the research, a decentralized power supply was thought to lead to a destabilization of the existing power structures. Meanwhile however, a coordinated local power grid is believed to have a very positive effect and can lead to a more robust network load. A decentralized production structure directly generated by the consumer power can also convey a new awareness and approach to one's own energy consumption. Consumers become producers and producers become consumers. Careful interconnectedness allows sustainable use of locally produced energy.

23,4% of power generated (as of 2013) through photovoltaics, hydropower and biomass is already a large part of electricity in Germany. On the whole however, the proportion of electrical and thermal energy generated from renewable energy sources is only at 7%. To implement the new energy policy in a rather ambitious timeframe, additional solutions must be found to increase the proportion generated from renewable sources from solar, wind, biomass, geothermal and hydropower energy.

Use of solar systems on buildings and in cities

For the implementation of technologies for renewable energy, the legislator seeks increasingly affordable uses of technology. Here, an annual additional construction in the use of solar energy of at least 2500 MW/a (gross) is foreseen. In comparison to a 2,500 MW/a for the onshore production of wind energy, this will be politically very beneficial. Solar energy needs an enormous amount of land that needs to be made available (under contract). Buildings and cities are predestined for the use of solar energy. Wind and hydro power on the other hand can only be used partially in urban areas. The already existing roof and facade surfaces of German housing are a great potential to use as surfaces for electricity and heat production. In addition, the solar energy supplied is in close proximity to the consumer. In residential property, the homeowner can produce his/her own required energy directly on his/her own land.

In the past 15 years, the solar energy production on buildings has made an enormous development. Electrical and thermal systems have, since the year 2000, systematically expanded. In the year 2013, a total of 3.8 million solar systems (solar thermal and photovoltaic systems) have been built in Germany. This has however been increasingly seen as critical. The main criticisms are the inadequate optical integration of active solar systems into the building envelope, the high energy and technical requirements of the construction of solar systems and the associated high costs. Solar active use should therefore be integrated into the architecture and not only be a technical additive element. There have already been very successful examples of this that are however not in the everyday building processes. It is a major challenge to develop the active use of solar energy as an integral part of the architecture. To this end, it is essential to integrate active systems into the building envelope.

Applicated application - integrated application

What is meant by integration in the context of building-related applications? The importance of integration in dealing with buildings is difficult to fully delineate. The type of solutions range from design principles to technical integration and provides many creative implementation possibilities.

The integration of solar active materials in the building envelope will confront planners, producers and executers with various kinds of barriers through out the building process.

Linguistically, the term ‚integration' is translated with the words "production of a unit, inclusion and inclusion in a larger whole". Synonyms of the word are unit, cohesion, fusion, embedding and inclusion. Nationally, the integrated application of solar energy winning systems in buildings is not taken much into consideration. A large part of what has been considered is the additive application that is mostly done in small to medium sized buildings (single and multi-family housing for example). Commercially available modules for solar thermal and photovoltaic energy are used to support the building and mounted in addition to functional roof and facade constructions. Occasionally even larger buildings such as exhibition halls, and car parks were also provided with solar modules particularly due to the large surface area available on the roofs. Here the installation also takes place mostly in addition to the actual roofing. This technique is failing to exploit the great possibilities of integrating solar active building components as a replacement for conventionally designed building shell constructions.

In Switzerland, there is a targeted support program that aims to increase the amount of solar energy-winning systems integrated into buildings. The idea to have a special promotion or incentive for integrating solar active systems in order to heighten the awareness of using solar active systems as a architectural design element is an innovative approach and, as seen through current examples, increases international competition and acceptance. Through policy limitations however, aspects affecting the aesthetics of an integrated system are not taken into consideration. So the concept of integration should touch several levels of building design and is limited only to a first approximation by the building policies.

The design aspect is an important criterion in creating an architectural-, urban planning- and social acceptance for successful integration. This research report strays away from policy limitations and shows a creatively successful building thats properly integrates an active solar system that does not show a recognizable “double function“ of an energy-winning system of an integrated solution.

The building situation and existing building type have varied requirements on installing a creatively and technically successful integration. If in the early planning stage, system-related solar active components are already taken into consideration, then a clear differentiation between an integrated and an appliquéd design is in most cases non existent. The planning of an installation on the roof of a hall constructions for example has very different priorities compared to a sensitively handled integrated design in an urban facade.

While the limiting factors of using a roof surface essentially consists of the structural conditions and competing roof structures, rather soft and more complex factors play a role in the use of surfaces in a facade in an urban area. Already at the beginning of the planning process is the consideration of intended execution on different phases essential - from the urban context to the material, color as well as the desired composition. The roof application on a hall on the other hand can, through the elevated attica and lack of direct view-ability planned in the early design phase, be creatively integrated into the building. In this case, the constructive and maintenance aspects become more important (static concerns, maintenance facility). Thus this integration of active components on the roof hall counteract the often recited statement that the integration generally leads to the use of more cost generating special or customized solutions that prohibit serial production or the use of standard modules.

2. Methodology

As described, the building-integrated solar application of active systems has so far not yet become a natural part of architecture. Systems are primarily added to a building and is not designed as an integrated component (roof, facade, parapet, etc.). This has lead to many reservations and further obstacles - resentments towards areas in artistic expression or design, technical integration or simply the necessary additional costs. The mentioned active systems are generally not rejected. Reasons for this are manifold and are from person to person quite different.

Impediment study
The presented work is devoted to the identification of barriers to the dissemination and integration of solar active systems. The aim is to create a comprehensive barrier catalog which categorizes, priorities and evaluates the found barriers and will then be used to find a strategy to overcome them.

Methods of qualitative research interview
The identification of barriers was based on a qualitative research interview. This method of reconstructive social research has proven itself over quantitative research in many aspects. The planned interview will ask major stakeholders (actors) in the field of architecture and solar energy. The aim is to gather a detailed understanding of mechanisms and patterns of thinking on the focused topic. The qualitative research interview focuses on the communication between researchers and the research subject. Openness is hereby a mandatory component throughout the interview. This also means that there can be no biased questions or remarks made by the researcher to the interviewed experts.

The interviewed experts musst be asked in a neutral, non biased way. Following Kruse, the present study defines the following objectives: • understanding complex issues in the installation of integrated systems • reconstructed subjective interpretation patterns of actors involved • keeping one's own preconceptions as far away as possible • understanding interpretations and subjective viewpoints • designed according to openness • open questions, the answers are texts • small samples (3-5 experts per group of actors)

Groups of actors
The first step is to form groups of actors, each with a different focus. Within each group, 3 to five experts with specific expertise relevant to the subject will be appointed. In the expert interviews, systematic queried barriers and possibly first strategic blocks will be investigated. This will be done separately by each group of actors. The interview is conducted on the basis of a previously developed questionnaire. The questionnaire serves as a rough guideline in carrying out the interviews. Besides the questions from the catalog, the interviewee will be asked more questions in greater detail if needed as to get into more information on specific aspects once he/she's expertise are recognized. Each interview is recorded as an audio file and then it is written down. The following groups will be formed:

- planning office – architect
- planning office – engineering
- politics
- clients and user
- utilities and operators
- association

3. Results

Aspects of integration

Building-related integrations, as illustrate in the preceding paragraphs, depends on different partly project-specific conditions. What is the development potential of integrated models for the recently established solar industry in germany to reach new fields of action?

The research project dealts with this issue and identifies barriers which demonstrate the low acceptance of integrated systems and prevent an increased usage of building integrated systems. The self-evidents in the usage of solaractive systems is becoming apperent as a major screw to increase the acceptance. In design terms, as well as in constructive issues different fields of activity are related.

The involved groups in the design and construction process have to develop possibilities which increase the opportunities of a flexibel architectual handling to overcome the still preceived character of technical applications.

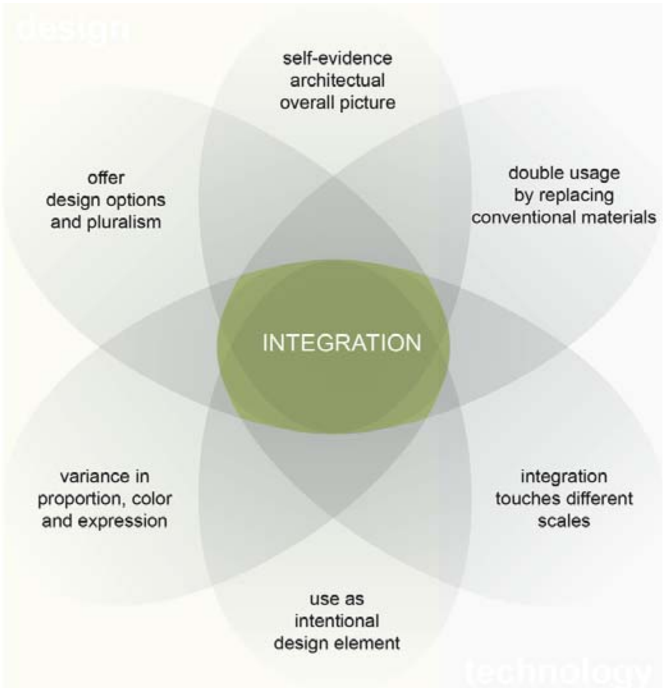

Fig. 1 influences of integration

In many realized pioneering efforts since the 1970s which combined architecture and active energy production often the aspects of energy production became the dominant character of the urbanistic and architectural impression.

Other approaches try to translate the strategic use of solar active elements in buildings in an architectural design element. In sensitive calibration of architecture with the desire for renewable energy production is the attempt to establish these energy producing elements as readable but natural part of the overall building-concept. It’s becoming an architecture expressing design element.

However, this principle of integration provides limited opportunities for e.g. large-scales usage or the embedding in urban context situations. This form of integration will primarily be applicable in individual objects and for representative buildings and is always going to have a clear readability in the building envelope.

Larger areas and contextually founded usages in the visible range of urban structures on the other hand require a restrained appearance of the solar-active components. The formation of a homogeneous appearance of the present urban situation or facades of individual buildings is an essential condition for the architect to draw a use of energy-winning materials into consideration.
Future systems should therefore provide the variance to be both an architectural design element as well as using the systems with project-specific colors, constructions and surface designs in order to achieve an integrated embedding in the surrounded situation.

Due to the different installation locations in a building, and various ways of integrating arising appropriate further significant obstacles that counteract an increase of built-in applications and have to be observed. Here the research project provides a comprehensive overview.
Therefore in the interviews conducted as part of the research project different integration options have been targeted and being polled.
The identified barriers have been filtered according to the categories of design, planning, construction and technology, economy and society regulation issues and been addressed to potential responsable insittutions - stating solution strategies.

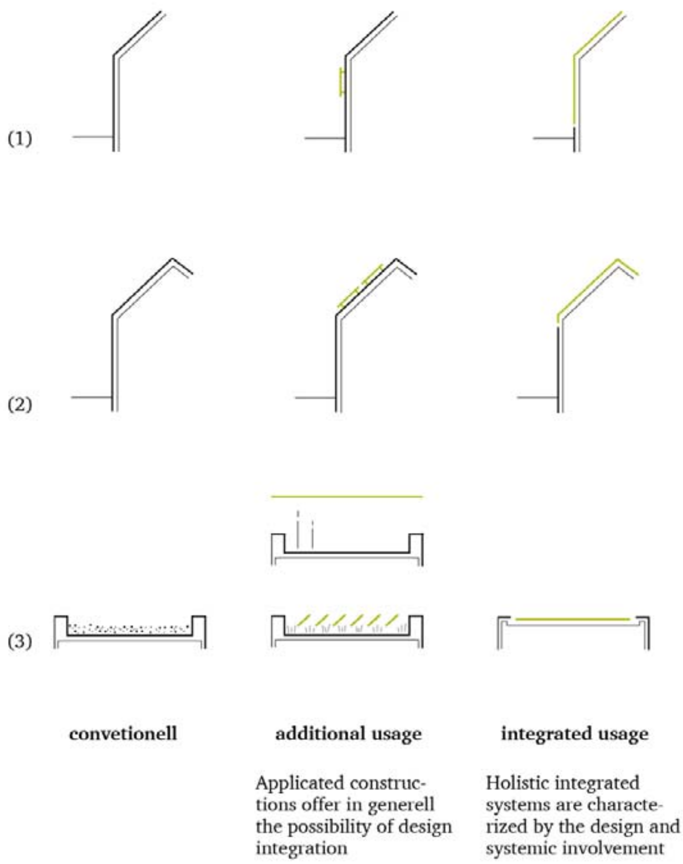

Fig. 2 integrated and applicated usage

Barriers and strategies for building related integration

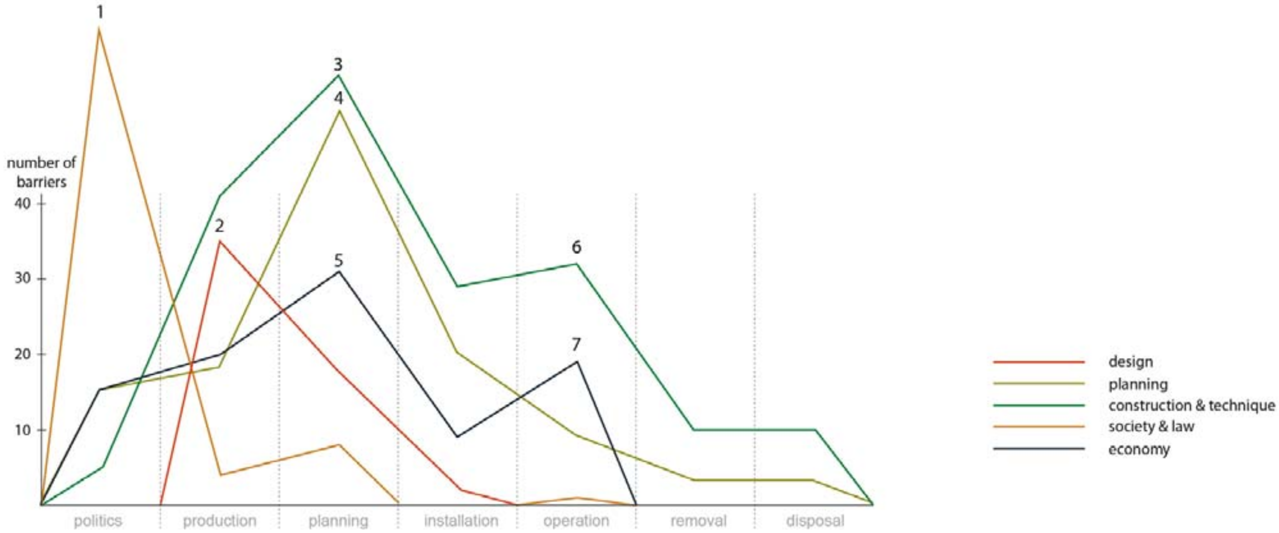

Fig. 3 barriers in the context of a buildings life-cycle, cumulated

The largest numbers of called barriers were pointed out in the areas of “society and law”, “construction and technique” and in the “planning” process. In addition, an essential field of action was typed out consurning "design" characteristics.
As one of the decisive social regulatory barriers a lack of impulse promotion - specifically for integrated applications - was mentioned (1). It needs to have perspectively regulations that create the incentive for builders to think about solar energy use in buildings during the start of the planning process. Switzerland as one of the first countries has ventured through a regulation for the targeted promotion of integrated solutions a first step in the direction of increasing the field of building related solar energy gaining.
The design-related barriers (2) have been seen to a large extent in the field of production. There is a lack of flexible design options dealing with the available systems. So far, architecturally attractive individual solutions can only be achieved through intensive planning efforts. It should be the aim to achieve a higher flexibility of expression and execution of systems. The most recognizable barriers were, however, identified in the planning process of a building. Here it comes, among others, to miss opportunities for the usage of solar energy gaining shell-constructions by the lack of early aspired integrated planning (3).
Optionally, this omission is based, however, on the lack of knowledge of the involved parties about the chances of solar active systems (4), so that they are not even included in considerations. It takes interdisciplinary-targeted training on the application of diversity that these systems are offering, to counteract the need of training for the planning actors.
Last but not least the economic factors limit the frequency of application. In particular, the integrated design, so far prevented the use of a serially produced product. There are custom made productions being needed which makes the purchase uneconomically (5). Therefore, it needs a change of paradigm in terms of evaluation of economic efficiency of the building as well as to increase the flexibility of production to perspectivly reduce the incurred additional costs.

4. Conclusion

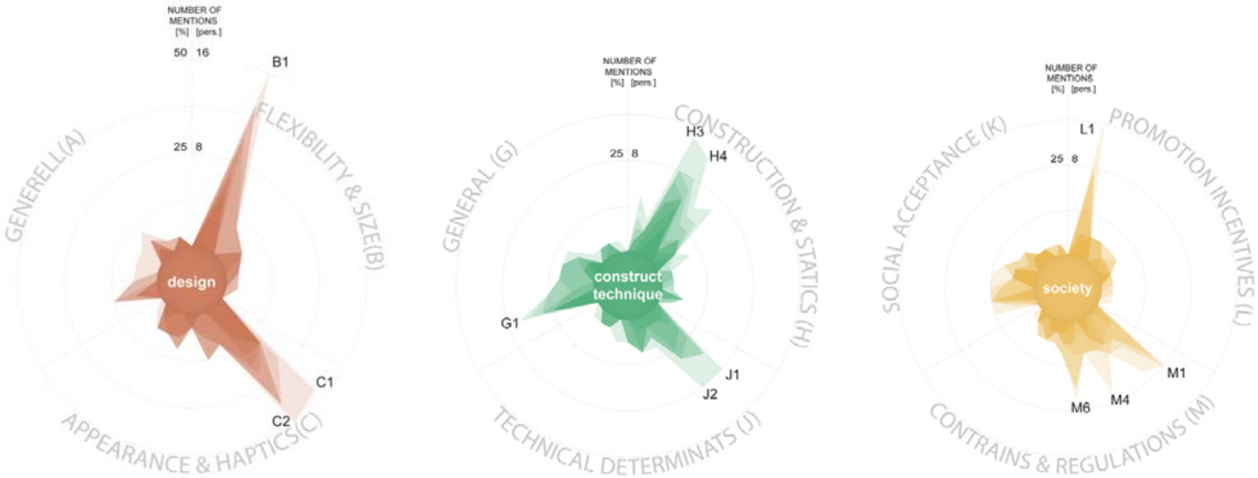

Fig. 4 examples graphics of barrier categories, cumulated (design, construction&technique, society & law)

The results show that there is a multi-layered approach to overcome existing barriers and to put the issue of increased solar active systems in the building envelope more into focus.
The introductory studies on the existing surface potential shows that there is great potential in the installation of energy-winning systems in the building envelope. The various types of these systems can be used significally more than it currently is.
In particular, building typologies that use these systems that underperform due to building structure optimization measures, have great potential through different creative and structural measures. The large surface area of available roof surfaces and facades of commercial buildings provide areas for the creative and appropriate integration of energy gaining systems in the building envelope.

Nevertheless, taking the European Building Directive 2020 into consideration, the already existing buildings should be focused on more and the various applications of creative and qualitative integration should be sought. Architects can achieve a “Nearly Zero Energy Standard“ through integrating energy winning systems into the building envelope. Companies that present appropriate and high-end solutions and provide the necessary flexibility in the production of such systems benefit by better meet the evolving demands. It is therefore the manufacturing trades as well as the contractors and engineers that need to shape the emerging market by pushing competence, creating great solutions and proactively investing in future products.

In general, the use of power-generating systems in the coming years is a pioneering technology discussed worldwide. The development of dye and organic cell systems appear to provide the best possibilities in design, application versatility with a maximum range in color, surface, transparency, form and materiality. The development of local energy production goes hand in hand with the need to further develop local energy storage. The concept and design developed power generating architecture, the decentralized storage of locally generated energy as well as the area specific grid stabilization will create a well thought out, energetically coordinated and socially accepted overall concept. Particularly in the urban context do building-related uses of solar energy - granted long and creatively successful solutions are found - arouse interest and generate demand since the building envelope (due to limited space in the city) provides the greatest potential for solar energy use.

The existing limitations in the use of energy-producing techniques in the building, discussed within this project, gives actors indirectly and/or indirectly involved the chance to further develop socially accepted solar active components in the building envelope by finding innovative solutions and provide impetus.

In this context, hybrid applications for certain building types and uses for the simultaneous production of electrical and thermal energy will be very relevant and interesting in the future. The crucial question is whether it will be possible to reduce the hybrid concept to a minimum amount of technology and the associated wiring.

Hybrid systems will be directly coupled with the underlying structure of the building so that the thermal components of the generated energy have a more direct usability to avoid unnecessary routing and penetrations. The systems should therefore have a large degree of flexibility to be able to respond to specific situational conditions. The development of such systems should have very promising results through the integral development and planning process.

All aspects mentioned in this report point to a strong demand that in order for sustainability to be socially accepted and to withhold long-term interests, appropriate and logical designs must be found that overcome it’s current mechanical or technical character.
It is however, important to not lose sight of the fact that a further financial burden of the public in the agreed expansion corridors is not expedient. Integrated and creative systems can only be accepted and long lasting if they do not lead to a cost increase of the EEG apportionment and the conversion of the electrical network. The success of the development of building integrated solar energy use will also depend on how competing systems will develop in the future.

The goal should be to lean towards regulations and subsidies that turn only short-term overarching guidelines into long term practices - triggered by acceptance forming base practices and the spread of knowledge - that will create a general social will for the demand of energy-producing building envelopes.

5. Acknowledgements

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Biocomposites for architectural applications based on the second generation of natural annual renewable resources

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Within this paper, the main concept and the development state of the research-industrial project, named “PLUS” are shortly discussed. The research is applied to find further sustainable solutions for contemporary buildings, through the development of new green building materials that are based on natural annual resources, replacing fossil-based conventional ones. The green materials are developed to be applied through innovative architectural designs in interior spaces, offering optimum thermal and acoustic insulation properties in the form of sandwich panels. These newly developed materials are dependent on the second generation of renewable bio-resources, represented in recycled agro-fibres derived from agricultural resources that donot interfere with food-supply chain. The developed materials should have a planned closed cycle loop, to maximize their sustainable benefits.

Keywords: Green building materials, Biocomposites, Life-Cycle, renewable resources, agro-fibres

1. Introduction

Biocomposites, is a term to describe a composition of a fibre and a matrix, in which at least one component is a bio-based one. In this research *agro-fibres* are applied with bio-plastics to reach pure *green biocomposites.*
Agro-fibres is a term to describe agricultural plant residue fibres, which is considered a second generation of renewable resources, after food-supply resources. Cereal straw is the highest available agro-fibre worldwide. Germany ranks the seventh among the world top ten wheat producers, representing almost 3.7% of the annual wheat production worldwide. In parallel, the annual Construction and Demolition wastes (C&D) amounts arises dramatically in Germany reaching up to 260,7 million tons in 2012 , according to the German Federal Statistical Office in 2012, providing about 64% of the total annual waste amounts annually generated. That reflects the importance of considering the end-of-life options of the applied building materials in our built environment. This strategy is applied through these types of biocomposites handled, as it is generated from upcycled agro-fibres and should at the end be completely recycled and/or composted. In this case, waste generation is prohibited, once within production and forever after applying the materials in building industry.

Many other products that are available in the contemporary markets, depend partly on biomass resources, in the form of combined natural fibres with fossil oil-based polymers.
Within this project, semi-finished product(s) in the form of sandwich panels are being produced, in which the outer layers are composed of an agro-fibre-reinforced biopolastic panel and the core of agro-fibre-reinforced bio-foam panel. The products should be applied in interior architectural applications in the form of partitions with thermal and acoustic insulation properties.

Agro-fibres resulted out of cereal grains in specific; with their exceptional chemical composition is our main focus. The high amounts of silica present in these types of annual plants, when compared to the non-annual wood are quite clear. This silica content is actually a draw back of the cereal crops agricultural resources when applied as an animal fodder, while it is of a great advantage if applied in other fields as the building industry. This advantage can be directly achieved in case of applying the natural fibres of the cereal agricultural resources with its silica contents, which has a direct fire-retardant's effect without extra mineral additives- in the form of direct fabricated semi-finished architectural products.

Combining these two parameters, agricultural residues and biopolymers, to replace the conventional non-renewable resourced architectural products in the market is our highlighted objective. The inner silica contents of the fiber will be investigated to be applied as a natural fire-retardant without the need for adding mineral or extra additives on the product. Fire tests therefore should be applied on the product(s) to define the material class that should be at least DIN 4102-B2 (normal flammable components). In addition, the outer wax layer on the fibre's surface, is also expected to work against the parasitism's attacks, fungal resistance as well as providing dimensional stability.

The following table indicates the inner chemical composition of two straw types, in comparison to soft and hard wood, to define their real potentials as a main green biocomposite ingredient.

Straw/Plant	Density[g/cm³]	Cellulose	Hemi-cellulose	Lignin	Silica	Ash
Rice straw	0.02-0.72 [1]	28-36 [3]	18–25 [4]	12-16 [3]	9-14 [3], 15-20 [5]	15-20 [3]
Wheatstraw	-	38-46 [3]	20–32 [4]	16-21 [3]	3-7 [3] /4-10 [4]	5-9 [3]
Soft wood	1.53 [2]	40-45 [3]	7-12 [5]	26-34 [3]	- [3] /<1 [4]	<1 [3]
Hard wood	-	38-48 [3]	20-25 [5]	23-30 [3]	- [3] /<1 [4]	<1 [3]

Table 1. Comparison between the chemical composition of cereal straws (rice and wheat) with that of wood (soft and hard).

Through the previous comparison, the real potentials of cereal straws are clear through the high contents of ash and silica, which are of anti-flammable characteristics that can be well used in building applications. In addition, silica works against rapid biodegradability which can be of much higher potentials when combined with biodegradable polymers, to increase the life time span as well as increasing fire resistance of the end product, that are of high importance in the building sector.

On the other hand, depending on the main components of the lingo-cellulosic fibres, fibres could be extracted and applied as a main biocomposite ingredient as here tackled throughout the research; and bio-polymers could be as well extracted as indicated through the following figure, where glucose derived from cellulose could be transformed to lactic acid, and accordingly to PLA synthesis. Similarly, lignin can be extracted to formulate lignin binders, or through hemicellulose extraction that can be transformed into a resin. Accordingly, the PLA and other bioplastics applied in this research within the developed green agro-plastic biocomposites, can be themselves derived from the lignocellulosic fibres applied, as described in fig. (1).

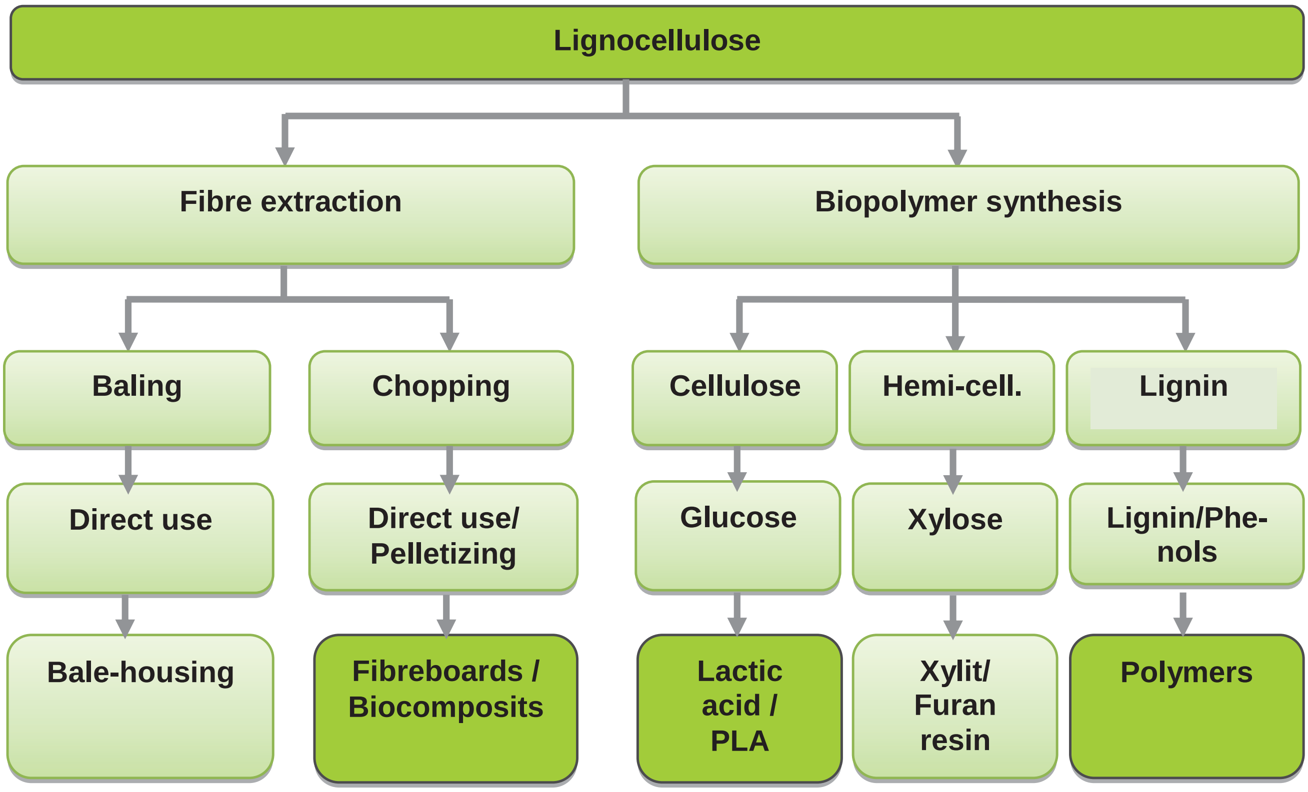


Figure1. Lignocellulose biomass as a source of natural fibres and biopolymers.

2. Methodology

The produced products should not be a burden on the environment, but should find their way back to the eco-cycle through recyclability, bio-degradability or through CO2 neutral energy winning.
The methodology of material development is dependant on the natural fibres prereration methods, agro-plastics processing possibilities and foaming techniques. Within the following, short description on each criteria is provided.

2.1 Natural fibres preparation:

The natural fibres applied were not chemically but physically treated. This was planned and achieved in order to reduce the other possible chemical wastes that can result from the treatment itself. The high silica content is expected to play an important role as a natural fire-retardent and the natural behavior of the untreated fibre with its outer wax layer would work as a defence line against fungus and parasites. To apply the highest possible dosing percentages of straw inspite of its low density, straw densification processing should be applied. For this process, one of the one of the project partners BaFa Neu GmbH is in charge.

Figure 2. Pelletizing Machine – BaFa Neu GmbH.
Photo credit: Dahy

2.2 Agro-plastics processing possibilities

Biocomposite's processing technique depend mainly on the type of binder applied and the physical form of the natural fibre.
The common compounding process takes place through the extrusion process by heating the thermoplastic polymer whether externally or through the mechanical shearing of the inner screw(s). For this process in 'PLUS', the companies Naftex GmbH and think-blue are in charge.

2.3 Foaming agro-plastics

Foaming agro-plastics is a challenging task, especially when physical gas foaming agents are applied. In this project, Leistritz Micro 27-40D machine is applied for this process, fig. (3). Regarding this process in this research project, the foaming group of the Fraunhofer-ICT is in charge.

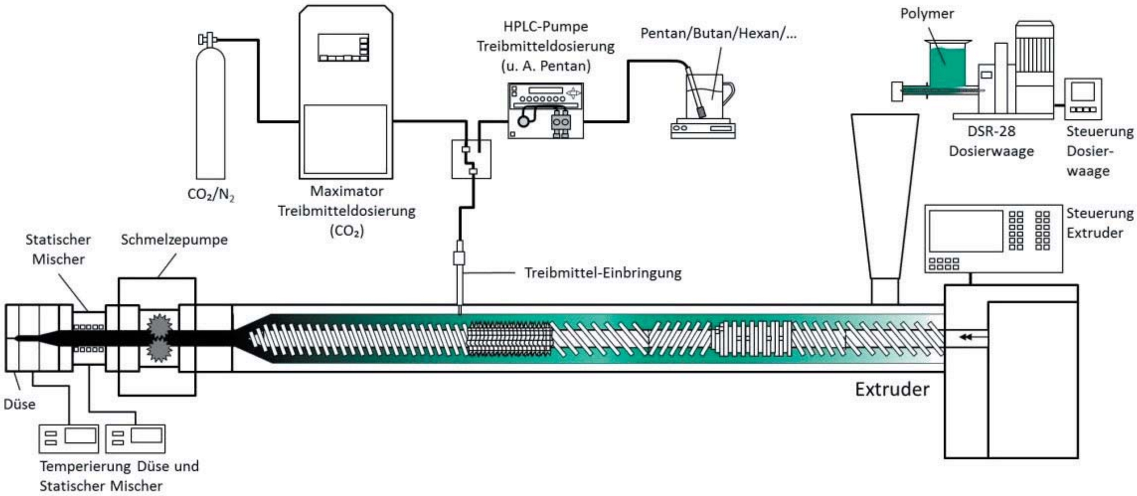


Figure 3. Foam extrusion machine – Fraunhofer ICT
Photo credit: Fraunhofer ICT

3. Results

3.1 Pelletizing and Extrusion

A number of chopping and grinding methods for the natural fibre's preparation stage, prior to the extrusion process, was studied. A mechanical modification technique was applied on the raw natural fibre without pre-chemical modifications. Within this process, the fibre's structure is opened, and the matrix is accordingly enabled to penetrate between the fibres and properly enclose them. Therefore, the wax surface of the straw should no more hinder the fibre/matrix proper interface, since the wax physical structure will be completely changed after the mechanical grinding and fibrillation process.

Applying this method guarantees the presence of the active silica contents that would replace the criticized health-risky and expensive flame retardants, which would be lost in case of classic chemical modifications. In addition, this should cause a reduction of the industrial optimization procedures of the natural fibre, prior to extrusion, which should be reflected on the reduction of the final product's price.

Within the following figure, fig. (4), different stages of mechanically treated fibres are shown, where the compact pelletized one was the preferable in dosing and is expected to enjoy the highest needed technical properties.

Loose | Chopped / hammer-milled | Pelletized

Figure 4. Different physical forms of the selected ligno-cellulosic agro- fibres. Photo credit: Dahy

Among the tests, pelletized natural fibres and PLA bioplastic were extruded in the form of roller shutters, fig. (5). In this case, natural fibres-PLA pellets were processed at 170 °C. This is one of the suggested techniques applied within the project.

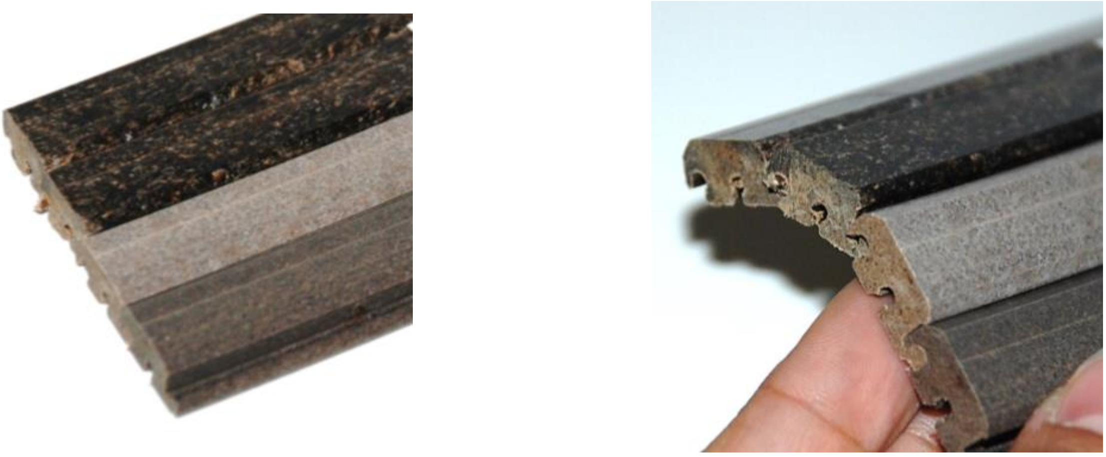


Figure 5. The extruded profiled roller shutters from the lingo-cellulose fibrils/PLA premixed pellets. Photo credit: Dahy

Another development was applied through extruding a room temperature pre-mixed straw/biopolymer using single-screw extruder, fig. (6).

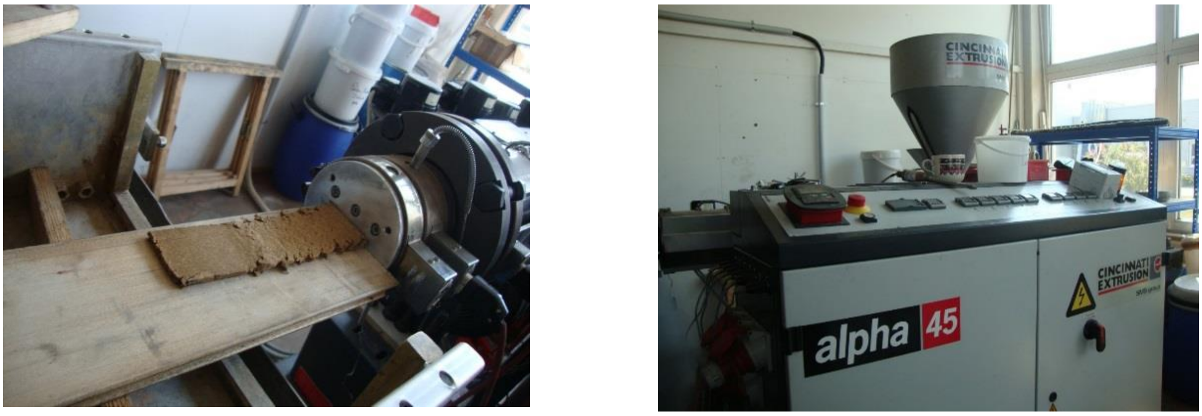


Figure 6. First extrusion samples of the natural fibres/PLA pellets using a single-screw extruder from think-blue company. Photo credit: Dahy

In this project, two main panels of two newly developed materials are to be manufactured. Straw-bioplastic composites, (Panel-1), can be extruded in plates and thermoformed, according to the required design, fig. (7). (Panel-2) is another safe VOC-free panel of reduced weight, as it is mainly composed of bio-foam reinforced with agro-fibres, where improved fire-resistance and thermal insulation performances are under development.

A- Compounding the fibres and the bioplastic within the twin screw extruder

B-The agro-fibre thermoplastic granulates after extrusion

C-agro-fibre-bioplastic plates after being pressed or plate-extruded

D-The mold is adjusted within the thermoforming machine

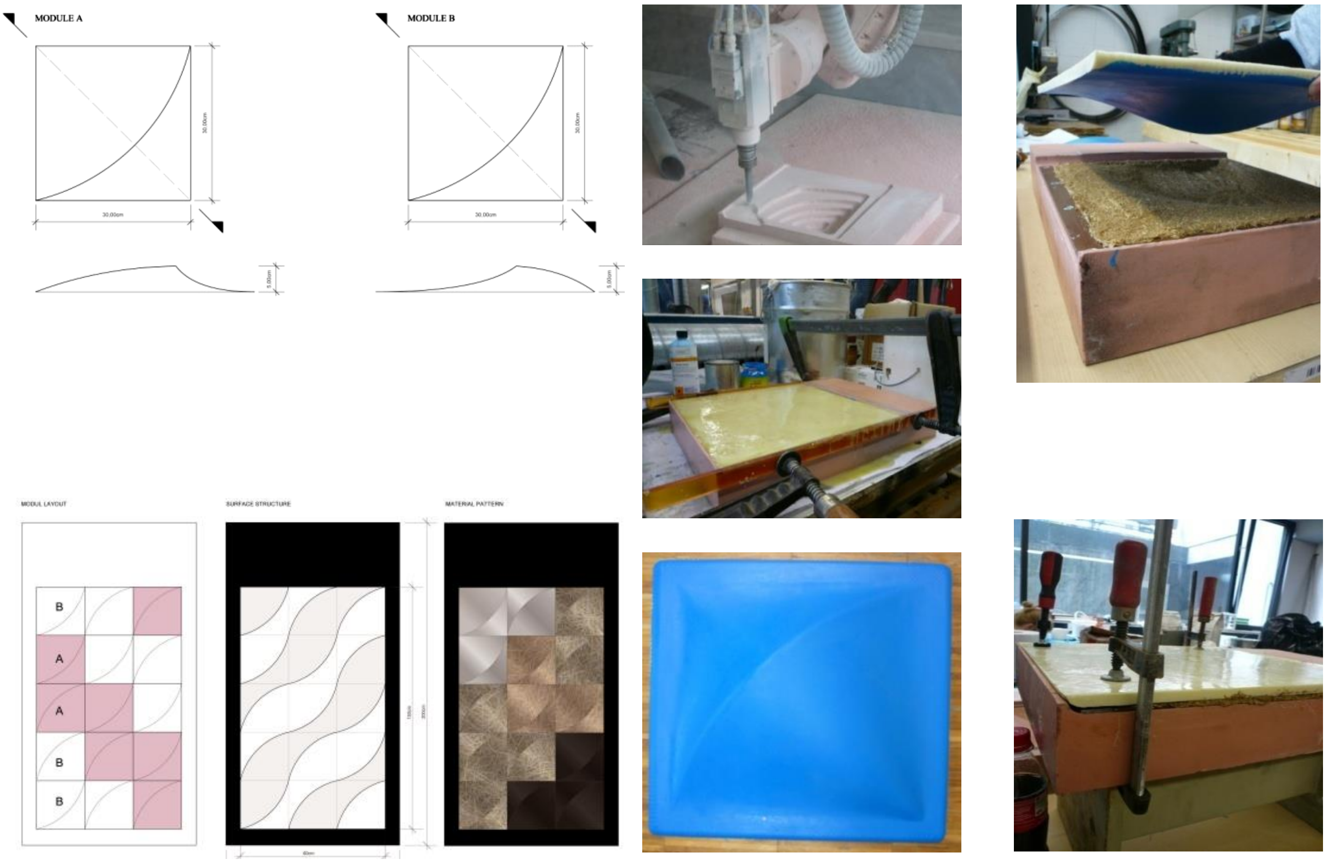
E-The thermoforming process simulating the agro-fibre bio-plastic thermoformed sheets

F-The final proposed product after fixation

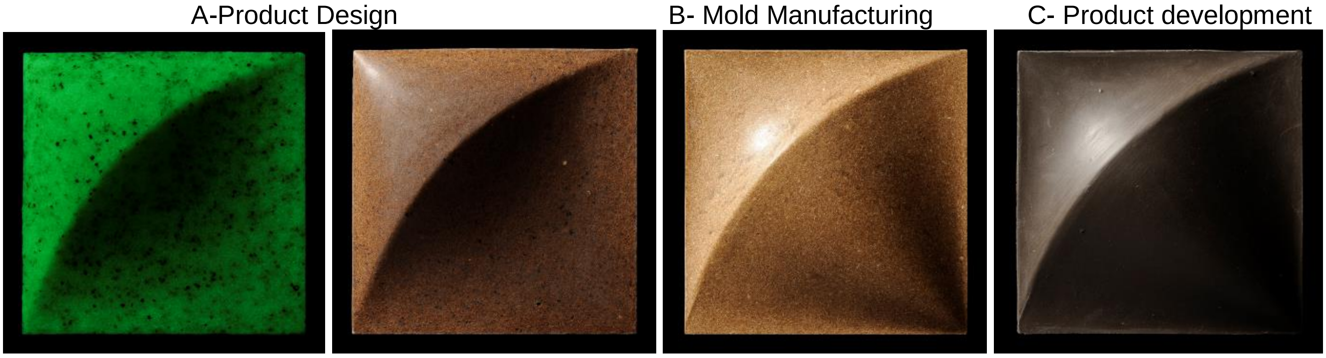
Figure 7. Illustration of the production procedures of one of the proposed developed green agro-fibre thermoplastic panels. Photo credit: Dahy

3.2 Product design concepts

The suggested agro-fibre-bioplastic and agro-fibre-biofoam combinations should not only offer different safe disposal options after the end-of-life usage,fig. (9), but also offer a wide variety of free-form and attractive agro-fibre-based panels in different architectural applications. The possible product-designs should be investigated within the ‘PLUS’ project and would be offered within ITKE- teaching classes in the University of Stuttgart, so that a large number of students could participate in the design-thinking process of the developed products. Through the planned design-thinking workshops at the University of Stuttgart, the industrial partners will participate to give their feedback on the feasibility of the proposed designs from an expert point of view, due to their direct customer-contact. The outcome should be in the form of 1:1 prototypes from the developed materials, applying the designs developed. These procedures are a common practice of ITKE, as illustrated in fig. (8), that indicates one of the products that was developed in an educational course offered by ITKE-University of Stuttgart.



A-Product Design B- Mold Manufacturing C- Product development



D-Final Product- different panels with different agro-fibres and glowing pigments

igure 8. Illustration of a number of biocomposite product-design developments in the framework of on
)f the ITKE-teaching classes at the Univeristy of Stuttgart, © Dahy, ITKE. Photo credit: Dahy, B.Miklautscl

4. Discussion

4.1 Economic Value

The value of adding these annual agro-fibres from an economical aspect is guaranteed due to their low cost. The price of straw varies in the international stock markets from 40-60 €/ton. Accordingly, high economic value would be expected with the high load of this natural fibre within biocomposites, to replace the polymers applied, which are in comparison to this fibre's type, more expensive.

4.2 Ecological value

4.2.1 End-of-life options

Applying straw fibres to the bioplastics would guarantee more options for the materials' recovery in positive manners back to the environment.

These options include recycling, composting through bio-degrading turning nutrients back to the soil, or incineration in safe-guarded conditions for energy recovery through different WTE (waste-to-energy) technologies, giving back the same carbon dioxide amounts once absorbed by the plants before their harvest, meaning CO_2-neutral green energy.

Accordingly green agroplastics would enable the reduction of carbon footprints represented in the greenhouse gas emissions.

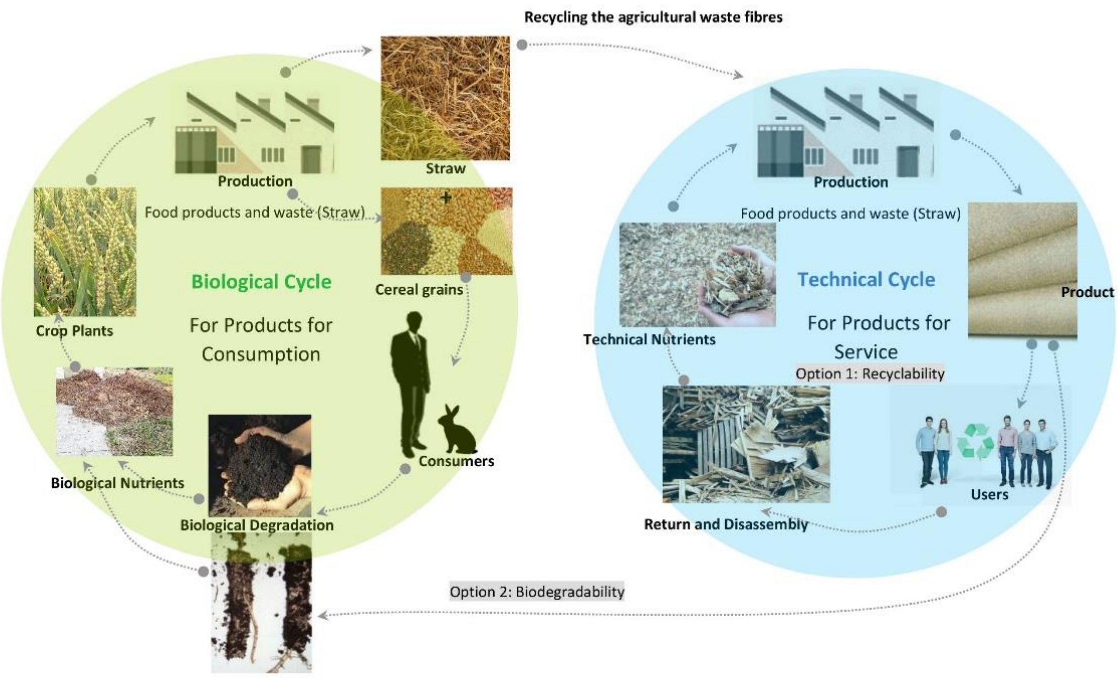


Figure 9. Diagram after the cradle to cradle® concept, emphasizing the environmental assessment of the developed product, according to both its recyclability and biodegradability possibilities. Credit: Dahy

4.2.2 Energy efficiency and CO2 foot-print reduction

For biobased resistant bioplastics, and evolved resistant green agroplastics cascading benefits at the end of their useful life-time phase due to their both materialistic and energetic benefits. This is due to the possibility of recycling the resistant bioplastic to a number of cycles, then still having the possibility to be fed into the regular waste stream of waste incineration plant for energy recycling. In this case, this type of energy supply after making use of the bio-based products for a specific life time, is much more resource-efficient than the direct burning of the bio-based fuels for energy uses, without any materialistic applications before the energetic ones.

Agro-fibres have minimum or no CO_2 footprint, since minimal energy is consumed to produce them. On the other hand, bioplastics - the second main component of the green agroplastic biocomposites - have much less environmental load than the fossil-based plastics.

5. Conclusion

Within this research project, sandwich elements of agricultural fibres and bioplastics are being developed. One of the materials is in the form of bio-based foam, in which agro-fibres are combined with bioplastics and foamed with an environmentally friendly foaming agent. Different economic and ecologic concepts are reached through these applications. The first developments were in the form of extruded roller shutters and extruded plates. One of the suggested products offer an environmentally friendly alternative to the classic MDF plates that are widely available in the interior architectural markets for partitions and furniture applications, accompanied by the known VOC emission problems, including formaldehyde and isocyanate ones in specific, which are carcinogenic as settled by the European Union, [7]. The other development should replace the classic fossil-oil based extruded polystyrene and polyurethane foams that are classically applied for thermal insulations, that have high drawbacks regarding the high carbon dioxide footprint and the dependence on expensive non-renewable fossil-based resources, in addition to the limited end-of-life options, especially regarding polyurethane foams.

Within this context, all “PLUS” partners are at the moment in cooperation iterative work, to develop the green bio-based sandwich panels. Among the tests, pelletized natural fibres and PLA bio-plastic were extruded in the form of roller shutters, fig. (5). In this production, natural fibres and PLA pellets were melt at 170 °C. This is one of the suggested techniques applied within the project. Another development was applied through extruding a room temperature pre-mixed straw/biopolymer using single- or twin-screw extruders, fig. (6).

In the markets, no bio-foams are yet applied in the building sector. It is a promising chance to develop this kind of thermal insulations to replace the fossil-based polystyrene and polyurethanes that are overwhelming the current markets.

ITKE- Univeristy of Stuttgart is coordinating this project and the concept founder, believing in the importance of the architects and building engineers’ envolvement and cooperation with material developrs, to reach the highest possible sustainability needed in built environments. It is crucial to investigate further renewable resources to be applied in the architecture field putting into consideration the official norms and building regulations, to reach through these renewable resources the high performance offered by the conventional materials in the markets, to be able to replace them. The developed materials within this project should be directed in the architectural field applications.

The agro-fibre-bioplastic and agro-fibre-biofoam plates can offer a lot of advantages that are still missing in the markets and are highly demanded by the customers, who are looking for safe interior plate materials with no emissions, attractive designs, acceptable mechanical properties, acoustical insulation performance and reasonable prices.

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Project Partners:
ITKE- University of Stuttgart (Coordinator) in Stuttgart.
Fraunhofer Agency- Institute of Chemical Technology (ICT) in Pfinztal.
K. Westermann GmbH + Co. KG in Denkendorf.

Other associated partners:
Naftex GmbH Naturfasertechnologie und Extrusion in Wiesmoor, think-blue: Extrusionswerkzeuge für technische Kunststoffprofile in Hohberg-Niederschopfheim, BaFa Neu GmbH in Malsch, Technisches Vertriebsbüro Burgstaller in Kirchanschöring.

Time outline:
01.01.15 – 30.06.17

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Building for the Gap.
Innovative engineering for housing applications in Africa.

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Summary

For many years the Bauhaus University Weimar, the University of Juba and the EiABC at the Addis Ababa University collaborated on visionary urban and architectural concepts, but also built experimental 1:1 housing projects. The very centre of attention have always been their inhabitants, their economic potential and the social interventions. Especially the enormous pressure of urbanisation calls for delicate solutions; a culturally manifested family and social cohesion inside existing neighbourhoods is being torn apart by the destruction of established city fabrics (slums) and the insertion of new, yet impersonal mass housing projects without any reflection to the way of living and social interaction.

Different prototypical buildings with different underlying impact were planned, built and tested as a potential model for housing in Africa. The first project focused on a natural resource from the agricultural industry utilized as build material for the complete house. The second prototype (re)introduce the potential of robust and tolerant prefabricated systems. The third prototype comes along with a parameterized numeric modelling and production technology to fabricate building parts, which allow self-made constructions in a high quality. All solutions are based on culturally and socially motivated design investigation and can respond to highly flexible occupation scenarios. The proposed building systems and adequate designs promotes economic, cultural and social sustainability by respecting existing ways of living while introducing improved contemporary housing standards.

Keywords: prototype, architecture, prefabrication, material, building modelling, Africa, participation

1. Background

Developing countries are experiencing extremely fast and unique urbanization processes brought on by a rapid increase in population, which in turn has produced a boom in the construction sector. In response to this situation, we need to develop fundamentally new concepts that are socially robust, open and flexible in their spatial structure and usage and that employ innovative building techniques with a low maintenance requirement [1]. Urbanization models from so-called ‘developed world’ based on centuries of continuous evolution or socially problematic concepts from second half of 20th century are clearly inappropriate and have to be reconsidered.

Current situation in Europe shows that such urbanization models are very much needed way beyond the political and economic borders of developing world. Due to military conflicts and human catastrophes, 60 million people are on the run, which is the highest number of migration since World War II. A seemingly unstoppable influx will lead 1 million refugees into Germany to the end of this year leading to the population grow level of the developing world. The agenda of the day must be re-invention of indigenous building methods, construction technologies, and material use. A solution for a socially accepted housing program has to provide a structural and incremental frame instead of a fully equipped apartment unit. The basis of “*incremental housing*” was that the cost of housing could be reduced by recognizing that poor urban families already build and extend their own dwellings incrementally in response to their needs and the availability of resources [2].

The requests for an affordable construction and open design are looking simple and easy to realize on a first view only. All the big governmental campaigns for social housing programs failed up to now. They ignore the potential of the people and their social network to arrange their own living environment. What designer, architects and engineers can do to promote economic, cultural and social sustainability? These are not only new conceptual methodologies, facilitated by emerging computer-aided technologies; expand the possibilities of the design and construction process. [3] [4] [5].

Hybrid concepts of this kind necessitate in turn a modular approach to construction so that worn or no longer morally tenable parts of the overall system can be replaced without incurring greater damage. Not coincidentally, the Bauhaus University with its historical backbone is a partner in collaboration with African Universities to initiate the experimental ways of an architectural design process in order to develop new standards for the next generation of architects. In this sense, the experimental research can be understood as a continuation of the experiments of modernism considering new challenges.

2. The interdisciplinary approach – three prototype units

The process of searching for alternatives in design and building will be a never-ending story in relationship to different contexts and their requirements. A consequence from these first steps of alternative constructing is to be more open for changing challenges and to be able to generate a creative atmosphere for designing, planning and building at all scales.
The scarcity of resources (building materials and their embedded energy) and the ever-increasing ecological challenges in both global as well as regional levels, demands a high degree of efficiency and sensitivity in the making of human habitat. State-of-the-art planning methods (parametric approaches, BIM, computational urban and building analysis) were used to translate these human needs and ecological demands into adaptable solutions, which enrich the high and increasing worldwide construction market. [6]. The multi-scale approach started from the detailed analysis and end with a usable, debatable product in a scale of 1:1. This process includes the idea development, considering the existing conditions, went to the conceptual design planning and testing of individual solutions and came out finally with the implementation and monitoring to learn about the potential for housing in Africa.

There was always a very specific interest and focus on each of those projects. SECU, the first project, invent a natural material from the agricultural business as a building material and is built out of it completely. SICU, the second prototype (re)introduce the potential of robust and tolerant prefabricated systems. MACU, the third prototype comes along with a parameterized modelling and numeric controlled production technology to fabricate building parts, which allow self-made constructions in a high quality.

2.1 SECU (Sustainable Emerging City Unit)

The project SECU focus on using alternative and local available, pre-processed building materials. Seasonal renewable resources such as straw could help meet the growing demand for construction materials. [7] [8]
It is a housing solution and constructional innovation, which is made entirely out of panels made of compressed straw (www.strawtec.com). The idea is to use straw in standardised shapes for modular building. In this case, it is necessary to close the gap between straw as a raw material and straw as an industrial or handmade product. Newly introduced construction methods are adopted to overcome the insufficient strength of the material. The panels available today are optimized by prefabrication; for compatibility within a building system and for the assembly process. (Fig. 1)

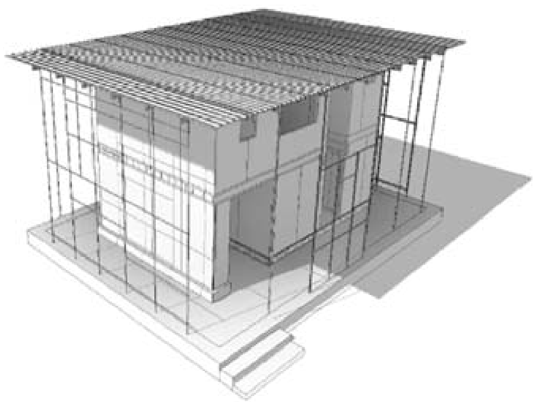

Fig. 1 SECU – Design and Building Information Model

All main structural building elements – walls, slabs, floors and roof – are made of single or double layered compressed straw panels (6 or 12 cm thickness), joined by threaded rods and casein-based glue. A secondary structural system is not required. The individual panels are produced in a continuous prefabrication process where the straw is compressed under heat to form a final product resembling a material comparable to soft fibreboard. For more details about see [9]. The significant roof overhang and green screen of climbing plants give the unit its own character and protects the straw panels from rainwater.

The floor plan layout creates a balance between open and enclosed spaces to provide the user with maximum freedom of use with 35m² on each floor and an integrated, water-resistant sanitation area. The standardized modules are out of prefabricated wall and slab units, which can be combined to various design permutations and guarantees a simple implementation process. (Fig. 2) Detailed information could be find at http://infar.architektur.uni-weimar.de/service/drupal-infar/node/827.

Fig. 2 SECU - the basic element : straw panels, half ready ground floor

As an alternative to the standard mass housing, this represents a possible solution for fast-growing urban agglomerations and provides extra income source for the farming sector. The prototype was built in Addis Ababa in 2012 (Fig.3). Another model case up to three storeys is under construction in Kigali (Rwanda) in 2015.

Fig. 3 SECU –the finished prototype

2.2 SICU - Sustainable Incremental Construction Unit

Fig. 4 SICU – Building Information Model; prototype made out of prefabricated elements only

SICU is a housing solution made entirely of prefabricated elements (Fig. 4). The solution uses locally available and locally produced building elements, and is provided as a semi-finished construction that the homeowners then complete themselves [10]. They can add the walls on the ground floor or enclose the upper landing to get more space. Simple building elements and a clear construction principle using prefabricated concrete elements (foundation and columns) are combined with lightweight timber frames and readymade wall panels with integrated windows and doors (Fig. 5).

Fig. 5 SICU – placing the prefab fundation (first day) and prefab cladding elements (sixth day)

It addresses the needs for participatory design through a process-oriented building typology. In the current implementation, with its accompanying business model and level of dissemination, it is possible to self-build the basic housing unit in less than two weeks using a mixture of local small businesses and participation from the local community. The modular design concept makes it possible to use for very dense and small plots and it can be used in combination to achieve economies of scale and create larger, flexible aggregate structures that fit into the surrounding urban structure. Almost 90% of the building components have been specifically designed and sorted for convenient development by small-scale business enterprises. [11]
Given that imported building materials, expensive customized processes and inflexible cast-in-situ systems currently predominate in the building sector, this shift presents a cost-efficient and faster alternative for the construction sector. All prefabricated building elements come in standard

dimensions according to a modular system. For more details about the prefabrication and the used building technology see [12]. Detailed information are on the webpage http://infar.architektur.uni-weimar.de/service/drupal-infar/node/828.

Careful and intensive preparation work preceded the processing and manufacturing of the elements to ensure that non-professionals can undertake construction and assembly using well-known connection techniques and those components match standard dimensions. (Fig. 6)

Fig. 6 SICU - the final result on the ninth day

A detailed building information model and a process model guarantees a consistent quality of production, predictable production costs, and programmable time schedules. Using a parameterized approach, the design system can quickly respond to different situations and design requirements, making it possible to quickly simulate and evaluate new design variants. Construction manuals, and business and financial investment plans are derived directly from the digital project model.

2.3 MACU - Mobile Automated Construction Unit

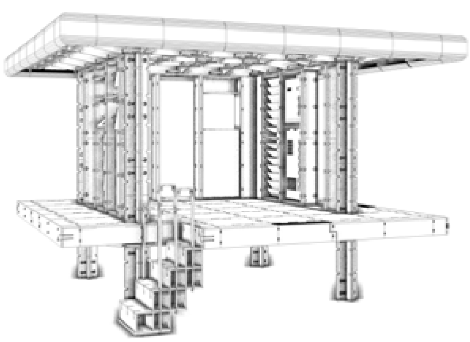

Fig. 7 MACU – the parameterized model, prepared for digital fabrication

MACU is the first known showcase for state of the art technology and production methods for flexible, individual and rapidly implemented building constructions in Africa. It is a forward-looking, technological alternative to existing knowledge in the building industry and as such intends to stimulate thinking in new directions (Fig. 7). The MACU prototype is a multi-purpose and flexible functional building unit, which is produced from high-end prefabricated elements. These sheets are customizable using computer controlled machinery [13].

The MACU demonstrates and proves the potential and impact of modern digital parameterized models, and the potential of modern planning methods, pre-processed materials and state of the art customised fabrication technology. All steps and production were undertaken in Africa (Ethiopia).

The design is based on a parametrized computer model that provides an instruction set for a computer-controlled milling machine, which produces the individual building parts. The concept of MACU affords a maximum degree of flexibility of the final building, guarantees a high degree of accuracy, and speeds up the implementation time on site by reducing errors almost to none [13]. The only material used is pre-processed eucalyptus plywood with a thickness of 18mm. Instead of plywood, other CNC process able material could also be used. The individual parts are assembled in relation to each other and fixed with connectors made of CNC-processed material (wedges, clamps, brackets, extenders). It is a temporary building structure and can easily be changed, extended and relocated. Assembly and disassembly is very straightforward. The digital model contains all the necessary information for production by a local CNC-milling shop (Fig. 8, left), including the quantities of material needed, the tags for identifying the individual building parts, the pattern for assembly as well as accurate costings for the entire process.

Fig. 8 MACU - CNC Milling Machine Workshop in Addis Ababa, assembling the ground floor

The parametric concept of MACU makes it possible to respond flexibly to different needs and situations and to produce an individual design by changing the parameters of the individual building parts (Fig. 8, right). The used technology may shows a direct alternative to existing methods more for temporary or individual buildings than for the masse housing program. It does not intend to replace nor question it, but simply to augment the possibilities. Its flexibility makes it possible to provide various functions to users. The usable space between the spacing of the column-grid ranges from 1.2 m to 3.8 m, with a maximum uninterrupted bay size of 28 m² usable space (Fig. 9). The column grid can be extended in both directions.

The structural system consists of prefabricated lightweight concrete pad footings into which columns are inserted that in turn are fixed to a grid-waffle slab system. The enclosure as well as the partitioning walls are non-loadbearing and can be placed in the grid of the slab (800 × 800 mm).

Various types of façades have been developed and solid walls (single or double sheets) or walls with openings for ventilation or even windows and doors can be placed individually. The roof is designed analogue to the slab with a removable membrane sheet which functions as a rain cover on the roof. Made of 1 mm thick PE, it is fixed over the projecting flat roof construction and secured from below.

The principle is suitable for individual functional units such as schools, kindergartens, offices, temporary houses, remote shelters as well as items in urban space such as information kiosks, bus stops, security post units, or for shaded canopies for public recreation. Detailed information are on the webpage http://infar.architektur.uni-weimar.de/service/drupal-infar/node/754.

Fig. 3 MACU – half ready construction and the finished one ((assembling time 10h)

3. The impact and value

The proposed way of building and the simple design promotes economic, cultural and social sustainability by respecting existing ways of living while introducing improved contemporary housing standards. The inhabitants could contribute with their own skills, adaptable techniques in contemporary circumstances and financial means to complete the structure according to their needs and wishes. This creates a need for parallel strategies to the existing Ethiopian governmental housing programs, allowing homeowners to remain in their existing local environment where their families have resided for decades and where they have established income and supporting social structures.

First we adopted the state of the art of planning technologies and conceptual design systems by the intensively use of shared design concepts, rapid prototyping modelling, use of integral communication platform by a centralized handled building and process model (BIM) [15]. The digital planning support system is the common basis for all the developed concepts and a major contributor

to cost-efficient buildings. This planning support system contains all quality and cost-relevant information for the respective different means of construction or the building system.
We handled all tasks with multiple scales too: Coming up with the general idea, to transform it into detailed and structured digital representation results, to test and evaluate it with physical models and to bring it to realization. Critical research challenges in this domain are the control of information organization, the translation from digital to physical reality without losing the initial idea and the problem of scaling up a design into a real prototype. Based on a set of defined spatial requirements (for example, number and size of rooms) and conditions (land use regulations, geometry of the site, existing materials and available cost budget), the system supported the finding of the optimal solution to directly determine the results of a planning optimization.

"*Never give up*" was the final motivation to come around with three different realized prototypical buildings with individual underlying impact. It should show on an extreme case the impact of a material, a process or a newly introduced production method. The teams looked for a dissemination and adoption to the mass marked too. By creating a full digital model of the buildings, the process steps and the business behind, the results are staying for experimental prototypes, which can easily go to the implementation on a wider scale.

Based on our experiences, we can proceed to more complex and cost-effective even multi-story housing that can adapt to individual needs and conditions. We recognized that it is less the technology itself, it is more the involvement of the people and the shared effort to provide identification, motivation for the inhabitants. The project is more successful if you just provide a "framework" as a starting point for the target group from the beginning. Further dissemination are currently ongoing and accompanied with the introduction of more variants and improvements. All those new implementations, which are based on those initial ideas, will give a wider proof and evidence of the initial concepts. Private companies as well as governmental institutions are transferring the prototypes into the mass market, which could not by realized by this time and budget limited project. The company STRAWTEC Ltd. Rwanda transfers the first house SECU into the housing market in Rwanda since 2015. The German Developing Association (GiZ) proof currently the chances for combining the vocational training in Ethiopia with the mass production of the second prototype SICU. The German Company ACKERMANN GmbH is starting a research project for a digitally based production of a starting house for apartment housing in Europe based on the prototype MACU. The project team itself will continue with the development and realization of a more complex prototype in 2016: an architectural intervention for the rural urbanization by a holistic neighbourhood design (around seven units) with an integrated urban and infrastructure concept.

Finally yet importantly, the outcome of the research and implementation can be transferred easily to equivalent European solutions. Europe is dealing with some of the challenges that Africa is currently facing. The potential to transfer the gained knowledge is given. The new inhabitants of Europa looking as well as the growing African population for open, user integrated and flexible design solutions, realized with simple and flexible construction principles.

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Building life cycle assessment: investigation of influential parameters in a helpful decision tool

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Summary

A building life cycle assessment tool was developed and linked with an energy simulation tool, allowing to take into account the strong interactions between the energy and the environmental performance of buildings. This life cycle assessement tool was then extended at the urban level to evaluate the environmental impacts of a district including many buildings, streets, public spaces and technical network. Building and neighbourhood design alternatives can thus be compared, providing assistance in the decision process. However, the reliability of LCA tool is essential to guide the decision maker towards sustainability. A methodology is presented here to investigate the most uncertain inputs. Parameters affecting the building energy performance and the choice of the electricity mix were identified as the most influencial factors which could alter the results' robustness.

Keywords: Life Cycle Assessment of buildings, Life cycle assessment of districts, Energy simulation, Robustness, Sensitivity study

1. Introduction

Because of its high environmental impact (energy and water consumption, waste production, greenhouse gases emissions…), the built environment has been identified as a key sector to face today's energy and environmental challenges. The quantitative and multicriterial life cycle assessment (LCA) methodology, according to ISO 14040 [1], is particularly adapted to study these impacts in order to make the building sector more sustainable. By comparing their environmental impacts, several projets corresponding to the same functional unit can then be ranked according to their performances.

In order to guide the decision towards the most sustainable alternative of a building or district project, robust LCA tools are necessary. Such tools should take into account the specificities of the building sector. For instance, the energy performance of a building or the interactions between buildings like shading phenomena must beaccounted for. Therefore, it was decided to link a building and district LCA simulation tool with a dynamic building energy simulation tool. The architecture of the model is described in the next section.

During a project, the LCA practitioner has to make a lot of choices (including hypotheses) which can potentially affect the results' robustness, i.e. the ranking of different project alternatives. Quantification methods like uncertainty or sensitivity analysis can be used to investigate the influence of uncertainties. The objective of the study presented herunder is to identify the most influential parameters met in building LCA. Uncertain parameters are therefore described (section three) and a sensitivity analysis method is applied (section four) in the case of a family house.

2. LCA of buildings and districts

LCA has been applied to the building sector since the 1990s. It was first used for buildings only and was then extended to the district level during the 2000s However, when assessing the environmental performances, the buildings and districts specificities should be considered.

2.1 Specificity of the built environment

Contrarily to most industrial products, a building is generally constructed only once: it is unique [2]. LCA practitioners have therefore little resources and time for a study. Dedicated LCA tools make such studies simpler if they are linked to a graphic modeller and an energy simulation tool.

When conducting a building LCA, it is important to consider all the building life cycle stages: the construction of the building including the fabrication of the building materials, the use phase, the renovation, and lastly the demolition including waste treatment. Due to the long building lifetime, the use phase is generally predominant. In conventional buildings, 80 % of the energy consumption is linked to the use phase [3], this part is however reduced to 50 % in low energy buildings.

Some choices made during the energy assessment of a building, like the choice of the insulation type or thickness, influence not only the energy performance but also the environmental performance of this building [4]. Some insulation material having better thermal performances may have higher environmental impacts. That is why, it is important to conduct both energy and environmental assessment together in order to estimate the global benefit of a choice.

Dynamic phenomena must also be considered in a building or district LCA. Meteorological phenomena and occupants' behaviour cause dynamic variations of the building energy load. The electricity production mix is also not static during the year. [5] showed that choosing a static (e.g. annual) or a dynamic LCA could have a large influence on impacts evaluation.

At the neighbourhood level, interactions between buildings and the surrounding context occur. For exemple buildings can shade each other. The entire district is affected by urban heat island phenomena.

Dedicated tools have been developed to assess the environmental performances of the built environment and take into account the sector specificities.

2.2 Description of the buildings and districts LCA tool used in this study

Due to the importance of the energy consumption in the use stage as well as the interactions between the energy and the environmental performances, a building and district LCA simulation tool (novaEQUER [6]) was linked to a dynamic building energy simulation tool (COMFIE [7]).

In COMFIE buildings are divided into thermal zones. For each of them, the temperature, and the heating and cooling loads are calculated with a 5 to 30 min time step by solving thermal equations. LCA can then be performed using novaEQUER. Building materials, thermal results (aggregated at an hourly time step), energy type, but also water consumption, transportation and waste produced during the use stage are taken into account. The LCA can be either static (e.g annual simulation) or dynamic (hourly load and hourly electricity production mix allocated to different uses [5]). Twelve environmental indicators are calculated (Table 1).

Table 1: Environmental indicators used in novaEQUER

Environmental indicator	**Legend (used in Fig. 4)**	**Unit**	**Sources**
Cumulative energy demand	(CED)	GJ	[8]
Water consumption	(W)	m^3	[8]
Abiotic depletion potential	(APD)	kg Sb equiv.	[9]
Non radioactive waste creation	(NRW)	t equiv.	[8]
Radioactive waste creation	(RW)	dm^3	[8]
Global warming potential	(GWP 100)	t CO_2 equiv.	[10]
Acidification potential	(AP)	kg SO_2 equiv.	[9]
Eutrophication potential	(EP)	kg PO_4^{3-} equiv.	[9]
Damage caused to ecosystems	(BD)	PDF.m².yr	[11]
Damage caused to human health	(HD)	DALY	[11]
Photochemical oxidant formation	(POP)	kg C_2H_4 equiv	[9]
Odour	(O)	Mm^3	[9]

In order to simplify the use of the tool, a dedicated graphic modelling tool (Alcyone) allows describing the geometry of all buildings in a district. When assessing the performance of a building, the others are considered as shading objects for a higher precision of the simulation results.

A module in novaEQUER concerns the district LCA. All buildings LCA results are included and the space around buildings is described. Different types of public spaces can be added as well as technical networks and the streets. The global software architecture is described in Fig. 1. The global architecture of the district life cycle is presented in Fig. 2.

Fig. 1 Software architecture of the model

NovaEQUER is a commercially available software. It is used by consultants or architects in the eco-design process at building or district scale. The decision-making towards a more sustainable project is facilitated because different alternatives of buildings or districts can be compared (with histograms or radar charts).

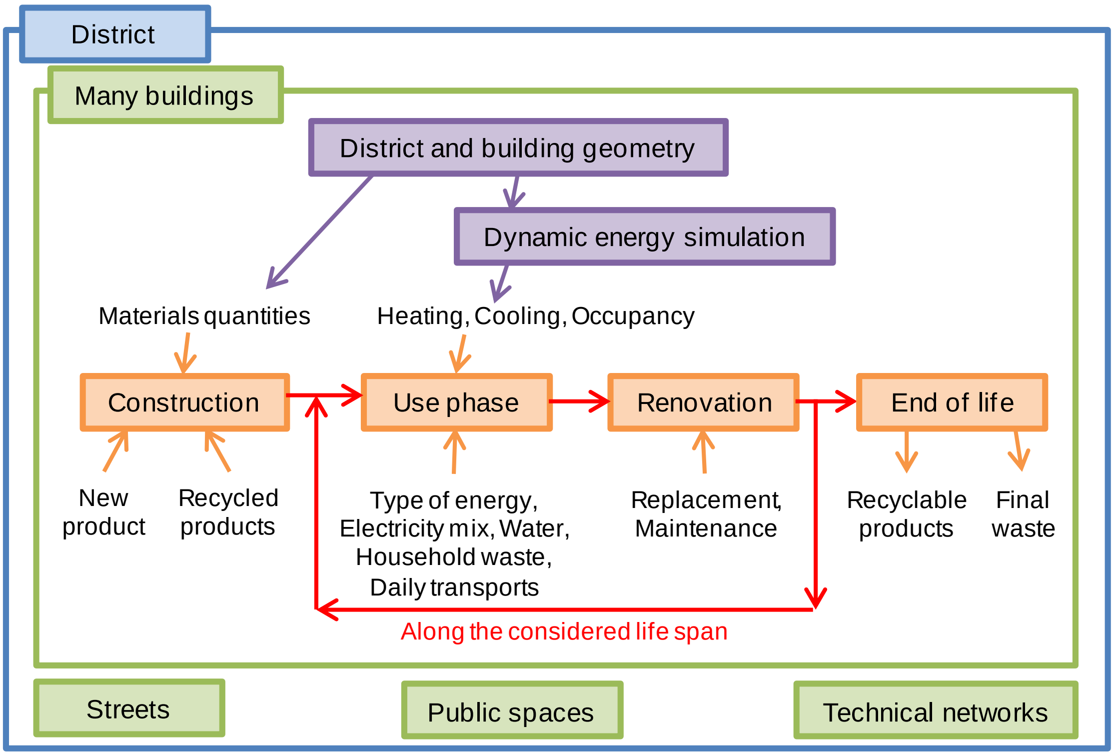

Fig. 2 Description of a district system, adapted from [6]

3. Reliability of LCA at the building level

If buildings and districts LCA tools are used in decision-making processes, they have to provide reliable results [12]. Otherwise, they may lead to decisions that are not the most sustainable [13]. However during an LCA study, practitioners are facing many choices. Inputs can be more or less uncertain and the uncertainty can affect the results robustness.

Results of different LCA tools were compared in research projects in order to investigate their robustness. Eight European tools were compared within the network PRESCO [14]. The results were similar and the scattering was +/-10% of the mean value between the tools when evaluating the greenhouse gases emitted during the entire life cycle of a wooden construction. In an other project, two French building LCA tools were compared [15]. It highlighted methodological differences in the tools as well as differences due to life cycle inventory databases.

In order to analyse the results' robustness of a building LCA tool when comparing alternatives of a project, uncertainty quantification methods can be set up. Uncertainty analysis (UA) is often used. With UA, uncertainties are propagated through the model, enabling to understand the uncertainty level in the outputs due to the input uncertainty level. The Monte Carlo method is often used to do this. As a result, probability distributions are obtained for each output. Another method, the sensitivity analysis (SA), aims at better understanding the uncertain results. In SA, parameters are ranked, in a quantitative way, according to their influence on the output uncertainty. SA is also called key issue analysis or uncertainty importance analysis in LCA [12]. A simple and quick SA method is presented herunder after having introduced uncertainty sources met in building LCA.

3.1 Uncertainty in building LCA

Five uncertainty sources that were identified in building LCA are described below.

- Hypotheses about the building: During the energy and environmental simulation a lot of hypotheses must be done. They concern the building envelope and systems, the occupant's behaviour (occupancy, water consumption, waste creation…), or the building and its components lifetime. These hypotheses are uncertain and a range of values around a reference value is considered.

- Long term evolution: Buildings have a long lifetime and the long term evolution of the context is largely unknown. For instance, the electricity production or materials end of life processes may change. Prospective scenarios, describing a large range of possible futures, can be used to model this type of uncertainty.

- Modelling methodology: Some aspect may be modelled in different ways in LCA. For instance regarding recycling, two allocation methods can be used: the cut-off approach or the avoided burden method. In the avoided burden approach an environmental benefit is considered because recycling avoids a standard production. This benefit is split between the construction stage (using recycled materials) and the end of life (recycling waste). In the cut-off approach, the benefit is only accounted for in the construction phase whereas no avoided impact is allocated to end of life, supposed to be in a far future so that the benefit is uncertain.

- Life cycle inventory (LCI): The way to inventory all emitted and extracted substances to the environment for building materials or processes also leads to uncertainty. Data availability and quality are drivers of this LCA phase [13]. The choice of marginal or average data for the inventory does not give the same image of a product or process. Additionally, simplifications of the inventory are sometimes conducted, e.g. gathering many substances in a single VOC (volatile organic compounds) group, which leads to the reduction of some substance effects (e.g. dioxins are more toxic than the average of VOCs).

- Life cycle impact assessment (LCIA): The aggregation of substances into environmental impact categories is uncertain. Indeed, effects of substances alone or of interactions between substances are not always well known. And the effect of substances may vary with the time and the emission location [2]. Finally some indicators like damage on health or on biodiversity are more uncertain because it is difficult to model the complex chain from emissions, transports, (bio-) degradations, concentrations, intakes and risks.

3.2 Sensitivity analysis: the Morris method

Uncertainty and sensitivity assessment requires a large number of simulations to ensure convergence of the results. At least one thousand simulations in UA or thousands of simulations in SA (with different values for the input parameters in each simulation) are required. The Morris method [16], which belongs to the screening techniques, has the advantage to be quick and simple to set up. The aim is to rank the input parameters according to their influence. It gives also information about the linearity and the presence of interactions.

Screening techniques allow a fast exploration of the model behavior. Instead of considering all possible values of all input parameters, only a few sets of values are kept. In fact, inputs are discretised into a finite number of levels (often 2 to 8). Thanks to this discretisation, it is not necessary to specify the probability distribution for each parameter; only an upper and a lower limit are required. Then an OAT (One-step-At-a-Time) method is repeated r times. Each OAT can be considered as a trajectory in the space of input parameters for which each input is varied while keeping the others constant. Elementary effect can be estimated for each input like in equation (1), where EE_j^i is the elementary effect of the j-th variable at the i-th repetition, f the considered model and Δ the jump between two discretized values.

$$EE_j^i = \frac{f\left(x_1^i,\ldots,x_j^i+\Delta x_j^i,\ldots,x_d^i\right)-f\left(x_1^i,\ldots,x_j^i,\ldots,x_d^i\right)}{\Delta} \quad (1)$$

Then the average elementary effect is calculated as in equation (2): the higher this average, the higher is the influence of the parameter j. By calculating the absolute value, the compensation of two opposite elementary effects is avoided.

$$\mu_j^* = \frac{1}{r}\sum_{i=1}^{r} |EE_j^i| \quad (2)$$

Lastly, the standard deviation is calculated as in equation (3). A large standard deviation indicates the presence of non-linearities or interactions between the input parameters.

$$\sigma_j = \sqrt{\frac{1}{r-1}\sum_{i=1}^{r}(EE_j^i - \mu_j)^2} \quad (3)$$

To get a visual result about the influence of each parameter, σ_j is drawn as a function of μ_j^* in a Morris graph. So three input types can be identified: inputs having negligible effect (small σ_j and μ_j^*), inputs having large effect without interactions (small σ_j and large μ_j^*) and inputs having non linear effect or interaction effects (large σ_j). Examples are presented herunder.

4. Case study and results

4.1 Description of the case study

The Morris method was applied on a case study to investigate the influence of uncertain input parameters. A single family house from the INCAS plateform in Chambéry (France) was chosen. It is a concrete house of 90 m² (living area) corresponding to the performance of the passive house standard [17] and using electric air heating (more details about the house can be found in [18]). The tools COMFIE and novaEQUER were used respectively to perform dynamic building energy simulation and LCA. The statistical software R was used to conduct the Morris analysis.

In this first study, a limited set of uncertain parameters were investigated (see Table 2). The uncertainty due to some parameters, like the waste production or the occupants' transportation during the use phase, was not taken into account in this first step. The variation intervals were chosen to describe the uncertainty on these parameters are given in Table 2. In some cases, the variation occurs around a reference value (+/-). That is the case for parameters influencing the energy performance. Because the house is already built and the location and occupancy are considered to be known or can be easily measured, a quite low uncertain range was chosen for most of theses parameters, (see [18] for more details about the ranges). The reference value for the scenarios corresponds to hourly mean values for a housing with four main rooms, (see [19] for more details about the scenarios creation).

Table 2: Investigated uncertain parameters and variation range

Uncertain parameter		Variation range	Sources
Climate and site	Outdoor temperature	+/- 0,5 °C	[18]
Climate and site	Global horizontal radiation	+/- 10 %	[18]
Climate and site	Albedo (ground reflection)	+/- 15 %	[18]
Scenario	Indoor temperature setpoint scenario	+/- 0,5 °C	[18]
Scenario	Occupancy scenario	+/- 10 %	[18]
Scenario	Internal gain scenario	+/- 10 %	[18]
Scenario	Ventilation scenario	+/- 10 %	[18]
Envelope	Windows thermal resistance	+/- 5 %	[18]
Envelope	Windows solar factor	+/- 5 %	[18]
Envelope	Insulation material thickness	+/- 0,5 cm	[18]
Envelope	Concrete thickness	+/- 0,5 cm	[18]
Envelope	Thermal bridges	+/- 50 %	assumed
Envelope	Material loss rate (during construction)	0 to 10 %	[20]
Lifetime	Building lifetime	70 to 90 yr.	assumed
Lifetime	Windows lifetime	15 to 60 yr.	[20]
Lifetime	Painting lifetime	5 to 50 yr.	[20]
Climate and site	Factory to site materials transportation	10 to 100 km	[8]
Climate and site	Site to landfill materials transportation	10 to 50 km	[8]
Context	Water network efficiency	70 to 90 %	assumed
Context	Electricity production mix	Static or dynamic	assumed
LCI data	Concrete type	Normal or prestressed	[8]
LCA method	IPCC time horizon	20 yr. or 500 yr	assumed

Most of the ranges were found in the literature, others were assumed. Regarding thermal bridges a high uncertainty range was considered because the literature gives a wide range of values for each thermal bridge type. The variation range chosen for the building lifetime can appear as quite low. It will be investigated in more detail later on when comparing the results robustness in the ranking of diffferent project alternatives. Two French electricity production mixes, implemented in novaEQUER were investigated: a static one considering an annual average and a dynamic one which varies hourly and for each type of use [5]. In order to take into account uncertainty due to LCI and LCIA, different types of concrete were considered (a normal concrete and a prestressed) and different time horizons were investigated for the global warming potential.

4.2 Results

460 simulations of the model were necessary to identify the most influential input parameters among the chosen uncertain parameters using the Morris screening. It took about 40 minutes with a six cores computer. A Morris graph plotting the standard deviation of the effect, σ_j and the average absolute effect, μ_j^* (eq. (2) and (3)) was obtained for the twelve environmental indicators calculated in novaEQUER, see Fig. 3 for CED and GWP.

For the cumulative energy demand (Fig. 3(a)), the drivers, identified by their large μ^* are input parameters having a strong influence on heating load (thermal bridges, indoor temperature setpoint, outdoor temperature). This confirms the influence of the building energy performance. The occupancy has also a high influence. Indeed, if there are more inhabitants, more domestic hot water will be consumed, resulting in a variation of the energy demand to heat the water.

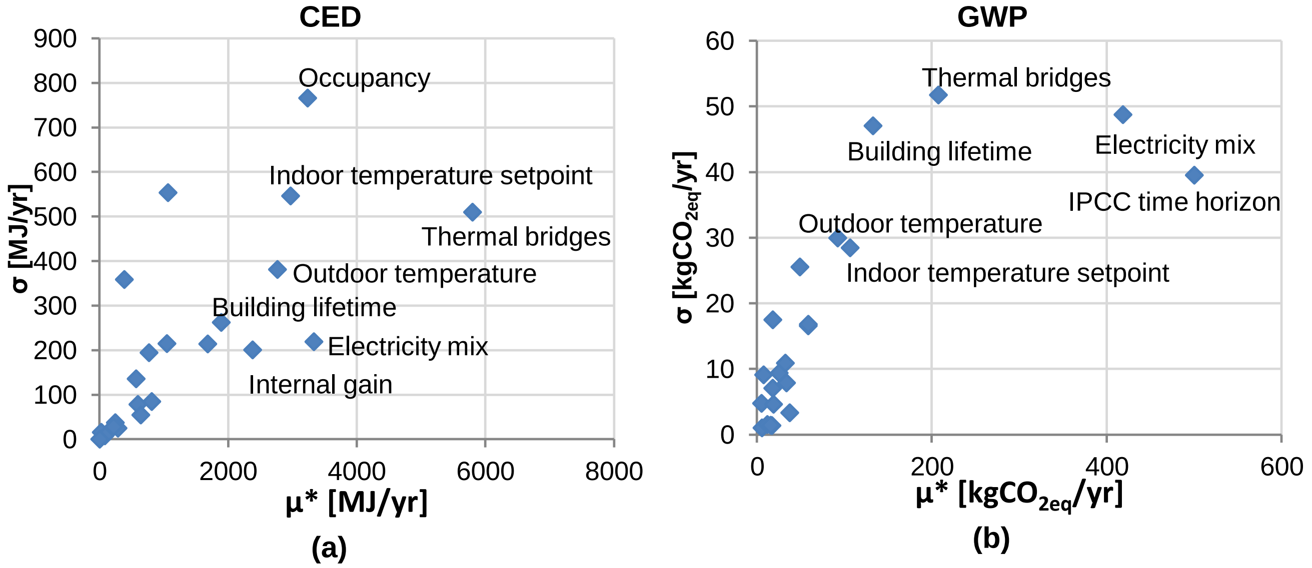

Fig. 3 Morris graphs for the CED (a) and the GWP (b)

For the GWP indicator (Fig. 3(b)), the IPCC time horizon has a large influence on the results. The type of electricity mix is also a major contributor. The most influential parameters for the energy performance are also prominent for GWP with a reduced effect. This is due to the the low carbon content of the French mix. Electricity being used at night for domestic hot water production the corresponding CO_2 emission is low (around 75% of this electricity being produced by nuclear plant) so that the influence of occupancy is reduced. Although the results are given per year, the building lifetime influences the results. It is due to interactions between this parameter and others like the windows or the painting lifetimes. A hypothesis in novaEQUER spitulates that the building components are not replaced if the replacement occurs in the last 10 % of the building lifetime.

Fig. 4 summarises the influence of the investigated parameters on the twelve environmental indicators. For each parameter j, the relative influence on the output uncertainty I_j^* is calculated considering the Euclidian distance to Morris graphs origins, as in equation (4). The most influential parameters for GWP and CED also have a large influence on the other environmental indicators.

$$I_j^* = \frac{d_j^*}{\sum d_j^*} \quad \text{with} \quad d_j^* = \sqrt{\mu_j^{*2} + \sigma_j^2} \tag{4}$$

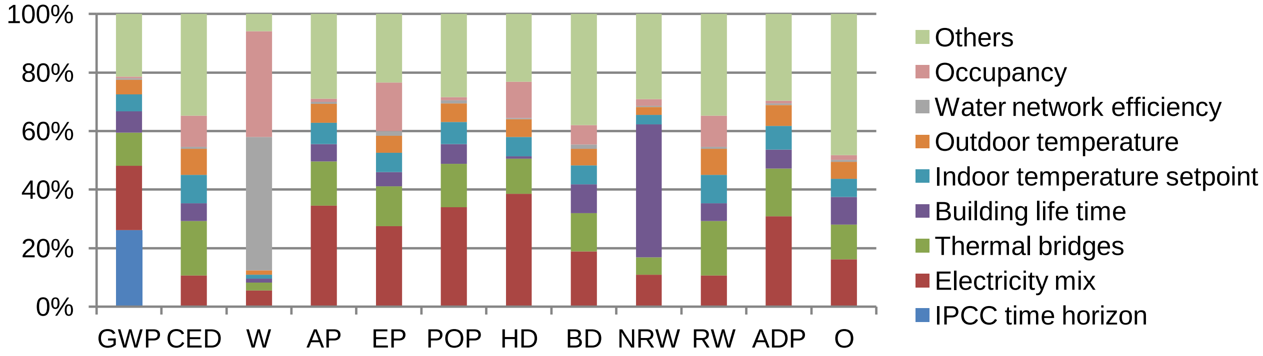

Fig. 4 Contribution of uncertain parameters to the global uncertainty

5. Discussion

Some parameters influencing the energy performance (temperatures, thermal bridges, occupancy) are also major contributors of the environmental performance. These results confirm the strong influence of energy issues in building LCA as identified in [2] and [3]. The chosen electricity production mix type has also a strong influence for most of the ten indicators calculated in novaEQUER because static and dynamic mixes do not have the same carbon contents. For water consumption, the water network efficiency is identified.

In this first study, a limited set of uncertain parameters was considered. For instance the influence of parameters like transportation of occupants or waste creation during the use phase, as well as the uncertainty due to methodological choices, was not taken into account. Uncertainties in the LCI and LCIA steps were also poorly represented. In a next step, these sources of uncertainty have to be investigated in order to have a better idea of the LCA drivers.Improving the knowledge on the most influential factors could lead to reduced output uncertainty.

Only one alternative of the project was considered but the final aim is to investigate the results robustness, i.e. to look at the possible change into the alternatives ranking. Furthermore, the case study concerns a single house but the method, which can be extended for more parameters, can be used for a district. Finally, no temporal evolution of the building or its context was considered. In the simulation, the same electricity production mix was used during the entire building lifetime. No degradation of the performance due to material wear was taken into account. However, this type of change can influence the environmental performance.

In order to evaluate more precisely the contribution of each uncertain parameter, sensitivity indices, like Sobol indices, should be calculated but their computation time depends on the number of input parameters. Therefore, it is preferable to conduct first a Morris screening to determine the most influential parameters. Then, sensitivity indices can be calculated after having excluded less influential inputs of the model.

6. Conclusion

The simulation tool presented in this paper enables to assess the environmental performance of complex systems like buildings and districts. Because different alternatives can be easily compared, it provides a design aid to progress towards sustainability in the building sector.

In order to orient the decision towards more sustainable alternatives, it is necessary to investigate the robustness of building LCA tools. Uncertainty and sensitivity analyses can be set up. A Morris screening was performed to rank uncertain factors based on their relative influence on the output uncertainty. In this first study, a few sets of uncertain parameters were investigated. In this case study, the most influential parameters are the electricity production mix as well as the major contributors to the building energy efficiency. The results confirm the influence of the energy performance in the environmental performance. In a next step, the influence of more parameters will be determined. Then uncertainty analyses will be carried out on comparative LCA to investigate the results' robustness: the ranking of different alternatives of a project according to the uncertainty on each alternative will be studied. Lastly this work will be extended to districts.

7. Acknowledgements

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Buildings as active components in smart grids

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Summary

In the EUREF research campus "Mobility2Grid", research is carried out on the implementation of a sustainable energy and mobility development in urban areas through the utilization of renewable energy sources.
During the first phase of the project Mobility2Grid different scenarios for the EUREF district with electricity generation from renewable energy sources and optimisation approaches for stationary batteries and electric vehicles were evaluated by using a simulation framework with regard to the degree of self supply and CO2 emissions. Selected results are presented.
In this context, buildings will be classified as components of an overall energetic system, and can actively contribute to control the energy consumption in dependance of energy production and thus smooth load fluctuations. CHP - and P2H technologies increase the flexibility. The integration of a thermal model into the energy optimisation and simulation environment associates especially storage, energy conversion, the heating network and the heat load displacement potential.
In this projectBuilding Information Modeling (BIM) supports different analyses to improve the overall energetic system. It links the building characteristics with the data of utilization and provides information for building energy simulations. The aim is to determine the building loads and the storage capacity of one or more buildings, depending on building condition, operation and also considering alternatives.

Keywords: smart grid, thermal storage, BIM, electro-mobility

1. The EUREF research campus Mobility2Grid

In the EUREF research campus "Mobility2Grid", located in the center of Berlin, research is carried out on the implementation of a sustainable energy and mobility development in urban areas through the utilization of renewable energy sources. The coordinated interaction of electro-mobility, power and heat supply networks is tested directly and experimentally on the EUREF campus.

2. Results of the first project phase

During the first phase of the project Mobility2Grid different scenarios for the EUREF district with electricity generation from renewable energy sources and optimisation approaches for stationary batteries and electric vehicles were evaluated by using a simulation framework [1] with regard to the degree of self supply and CO2 emissions. The first scenario contains all buildings as electricity consumers, which are planned for the year 2020, and the currently installed electricity producers based on renewable energy sources and energy storages (see [2]):

- Mostly office buildings with an expected demand for electricity of 8.75 GWh/a and heat demand of 11.66 GWh/a
- Solar collectors with a peak power of 73 kW_p
- Wind turbins with a peak power of 6 kW_p
- Heat-operated combined heat and power (CHP) units with a peak electric power of 422 kW_p and peak heat output of 562 kW_p
- Stationary batteries with a capacity of 174 kWh and a maximum power of 1C

The metered power curves of selected buildings, solar panels and wind turbines as well as the metered biogas usage of CHP in year 2013 were scaled up to the whole EUREF respectively. Additional needed electricity will be obtained from the distribution grid and additional heat energy from a gas-powered central-heating boiler.

Table 1: Degree of self supply according to installation of CHP and RES (PV and wind turbines)

	1 x RES	3 x RES	20 x RES
1 x CHP	24.9%	34.8%	43.4%
3.2 x CHP	56.6%	57.6%	65.3%
5 x CHP	61.1%	62.1%	69.4%
6 x CHP	61.3%	62.3%	69.6%

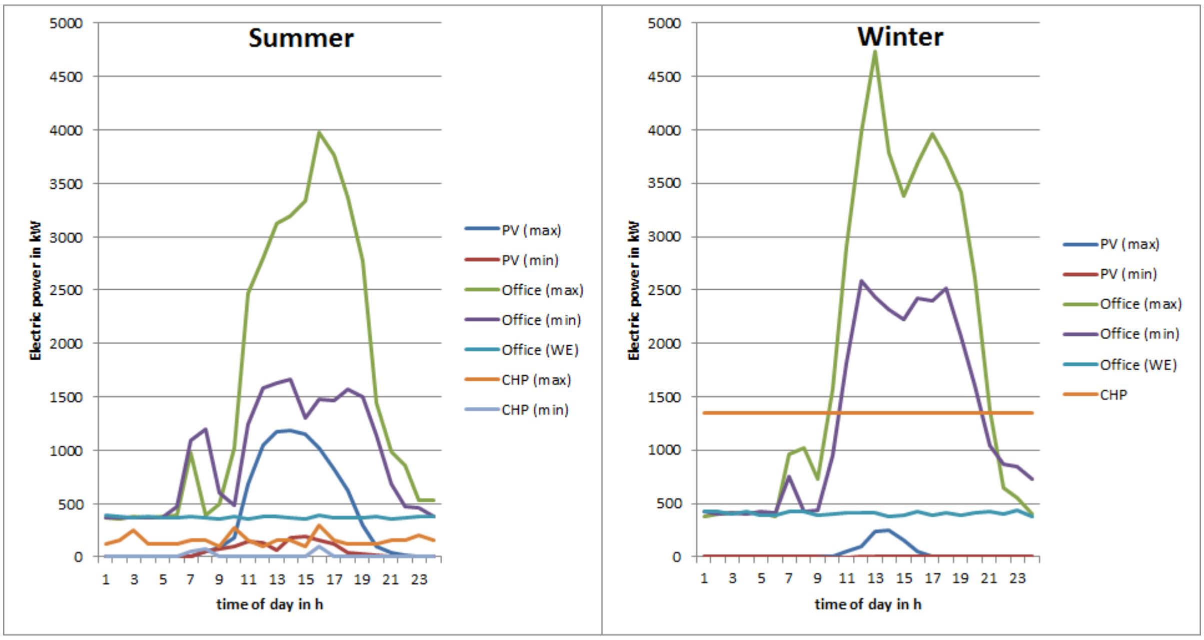

Fig. 1 Maximal and minimal power curves for buildings, PV and CHP

The analysis of the simulation results has shown that the planned installation of CHP with a peak electric power of 1,350 kW_p (3.2 x CHP) together with an additional installation of solar panels with 1,460 kW_p and wind turbines with 120 kW_p (20 x RES) will increase the degree of self supply from 24.9% to 65.3% and accordingly reduce the CO_2 emissions without appreciable usage of energy storages (see Table 1). A further installation of heat-operated CHP units will only have little effect due to the saturation of the heat demand.
For this scenario (3.2 x CHP and 20 x RES) Figure 1 shows an electricity surplus at sunny summer weekends due to solar panels as well as at winter weekends and winter nights due to the heat-operated CHP units. On the other hand, a big part of the demand for electricity has to be obtained from the distribution grid during the work hours. Therefore, the degree of self supply can be further increased by energy storages depending on the scenario (see Table 2). For example, a stationary battery with a capacity of 3,500 kWh (20 x Bat) and an efficiency of 90% is able to further increase the degree of self supply up to 5%.

Table 2: Degree of self supply according to installation of stationary batteries

	0 x Bat	1 x Bat	5 x Bat	10 x Bat	20 x Bat
1 x RES, 1x CHP	24.8%	24.9%	25.0%	25.0%	25.0%
3 x RES, 3.2 x CHP	57.3%	57.6%	58.8%	60.4%	62.4%
20 x RES, 5 x CHP	69.1%	69.4%	70.5%	71.7%	73.2%

A similar effect can be reached, if V2G-capable electric vehicles are used for commuting or business trips instead of a combustion car. All these vehicles with a capacity of 6,000 kWh in summary are necessary, because not all vehicles are connected with the smart grid at EUREF in the relevant periods.

The results of the first project phase will be consequent extended in the main phase of the project with the integration of buildings as active components for consumption and storage of thermal energy.

3. Vision: Buildings as an integral part of the smart grid

With further expansion of renewable energies, there will be increasing fluctuations in the supply of electrical energy. Load management and storage are the answers for the future. Besides pure electric (battery) storage, thermal storage is gaining importance. Using compression heating or cooling systems or directly by means of a heating element this heat store is electrically loaded to deliver thermal energy for heating or cooling at a different time. These methods are called "Power-to-Heat"- or short P2H technologies. Storage options, which exist per se and thus require no further investments are of particular interest. Buildings with their structure are such options, since walls and ceilings form a heat storage capacity by their construction material such as stone or concrete. Lakeman and Hauser [3] estimate the thermal capacity of Germany‘s residential buildings to about 1 TWh/K.
Room temperature changes of 1... 2 K are barely noticed. Plusminus 0.5 K are almost imperceptible, but already show this potential. Thus, interesting options arise:

- At times of excess availability, electricity is very cheap and can be used using P2H for deliberate overheating or overcooling of buildings to just 0.5 K or maybe more. The occupants will not perceive anything. Due to the storage capacity of the materials and the insulation of the building envelope the extra energy is not lost.

- As soon as the electricity surplus changes to a lack of electricity, heating or cooling can be switched off vice versa as long as the set temperature in the heating case falls below the selected tolerance, or exceeds it in the cooling case.
- In the case of electricity generation by means of a cogeneration plant, it may be operated in a power-oriented mode and use the cogenerated heat in the building as described above.

In the future, buildings will be classified as components of an overall energetic system, and can actively contribute to control the energy consumption in dependance of energy production and thus smooth load fluctuations. CHP - and P2H technologies increase the flexibility. The integration of a thermal model into the energy optimisation and simulation environment associates especially storage, energy conversion, the heating network and the heat load displacement potential.
With the analysis of an optimized energy management, an economically feasible application of CHP - and P2H technologies will be examined. The integration of buildings and their load profiles into the overall energy system takes place within a building model (building information model, BIM), which maps all system interfaces.

4. BIM as a tool

According to Egger et al. [4] BIM is a digital image of the physical and functional characteristics of a building from the first stage of appraisal or analysis of basic requirements and definition of the exact project scope to the stage of demolition. As such, it serves all kind of building information and is data platform for collaboration across the entire lifecycle of the building. In this regard the consistency of information is an important aspect. Based on the life cycle phases, the costs incurred in the realization and the utilization phase are the highest. Thus, the strategic decisions for the utilization phase are already made in the planning and implementation phase, in order to exploit the existing potential for optimization. In this sense the objective is to make the level of information of the first phases available for an improved operation in the utilization phase. To this end, a virtual three dimensional (3D) building model is used, which contains in addition to the graphical data also alphanumeric data, in the form of building characteristics and other property features. This information can be used by different stakeholders for different purposes in various building stages.

Compared to the traditional approach with 2D models the information which is included in the BIM can be considered as superior because the model information can be structured according to different classification aspects, such as spatial structure or technical structure of the system. Due to the high number of participants, each with a high level of specialization and also due to different legal frameworks, particularly in the form of guarantee, there is no overall model on which all participants work. Instead of that there are various specialized sub-models that will be combined to various specific cooperation models for the users involved. The usage of sub-models also enables the project participants to identify the exactly needed information in a short time because of a better overview. Furthermore the appropriate combination of different specified information models even provides an increase of information, for example by collision tests in the field of heating, ventilation and air conditioning (Krämer [5]).
However, the building model itself is only one part of the BIM methodology. Addressing the needs of different stakeholders in the different lifecycle phases, a variety of significant applications become apparent, which require new methods of working and organizational structures for networked and interdisciplinary processes. Thus, within the meaning of BIM, 4D planning is the integration of scheduling. 5D planning includes cost aspects and 6D and 7D planning are already associated with facility management applications and take aspects of sustainability into account.

This consideration is currently subject of continuous development. Figure 2 gives an overview of different BIM applications in the lifecycle of a building (Krämer [5]).

In addition to cost-effective planning alternatives, increased predictability and prevention of deficiencies as well as the simulation of the building operation and the creation of energy balances or carbon footprints may be also listed as an advantage of the methodology.

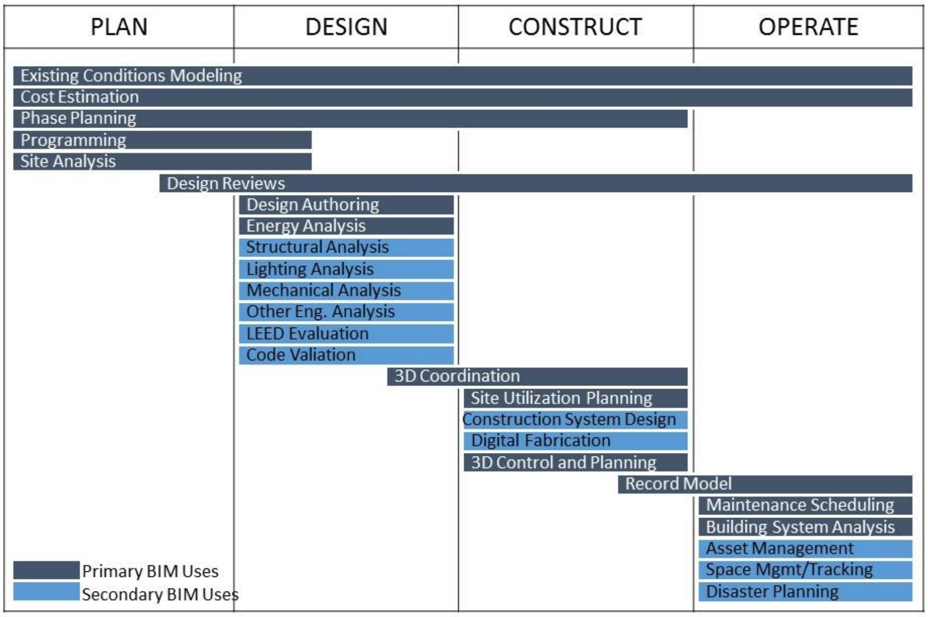

Fig. 2: BIM applications in the lifecycle of a building

In this project, in the context of EUREF Camus, BIM supports different analyses to improve the overall energetic system. It links the building characteristics with the data of utilization and provides information for building energy simulations. The aim is to determine the building loads and the storage capacity of one or more buildings, depending on building condition, operation and also considering alternatives. In terms of an overall improvement and based on a systematic implementation of the building structures in the load management of the campus, the results allow a positive effect on the control of the energy components, such as a combined heat and power unit (CHP). Regarding this the target is to operate the CHP in an efficient way, to bear in mind that there are not only technical requirements to fulfill but also economical requirements like fluctuation of price at the electricity stock exchange. In addition, also a significantly improved basis for the evaluation of energy indicators is caused during building operation phase. With regard to the respective use simultaneously increasing energy efficiency can be realized.

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Buildings energy retrofit: dealing with uncertainty

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Summary

Over the span of the past decade, the interest in issues related to building energy efficiency has been ever growing. Consequently, an increasing amount of studies has focused on the economic viability of energy retrofit measures. Despite all these research efforts, the results are still uncertain and conflicting. Nonetheless, such studies have brought out the main variables affecting the economic feasibility of interventions improving building energy performance: savings-investment ratio, cost-effectiveness of energy supply, energy price trends.

The aim of this paper is to investigate the relevance of an often disregarded aspect: the rate of time preference as an expression of households' behaviours, that is to say, the discount rate adopted within several valuation approaches, which are based on discounted cash flow. A case study analysis is performed on a refurbishment project. It concerns a public housing estate, built during the seventies, located in the suburbs of Bologna. A number of retrofit alternatives are examined, by resorting to different judgement criteria, particularly the Net Present Value.

It is shown that uncertain results may occur repeatedly, more frequently than literature has evidenced. Moreover, unclear outcomes closely correlate to the discount rate level, which may lead to conflicting options; therefore, it is hard to unequivocally identify the alternative characterized by the highest NPV.

Keywords: Building energy efficiency; uncertainty; property investment valuation; Discounted Cash Flow; discount rate.

1. Introduction

In the Italian context, the building performance issue entered into the political debate during the mid-seventies. As a consequence of the Oil Shock, the Law 373/1976 provided a first set of rules to reduce energy consumptions of residential buildings, focusing particularly on the standards required to be met by the building envelope and the heating installation. Subsequently, a major update of the legal system in this matter came into being fifteen years later, with Law 10/1991, which has enforced the so-called first national energy plan. Latest developments have been fostered by the EU energy policy: two main steps have been accomplished by Directives 2002/91/EC and 2010/31/EU, which have been acknowledged in the national territory by Legislative Decree 192/2005 and Law 90/2013, respectively.

Despite the aforementioned efforts, energy efficiency still represents a trend issue within the building sector. Indeed, according to Eurostat [1], residential and tertiary buildings account for about 40%

of energy consumptions and around 36% of greenhouse-gas emissions. Moreover, the European Commission [2, 3] has repeatedly stressed the remarkable unexpressed potential to improve the building performance, in view of the unsatisfactory results achieved so far.

While growing the interest in building energy efficiency within the political and academic debate, as well as in the industry sector, an increasing amount of studies has focused on the economic viability of energy retrofit measures. Despite that, the results are still uncertain and conflicting. However, such studies have brought out the main variables affecting the economic feasibility of interventions improving building energy performance: savings-investment ratio, cost-effectiveness of energy supply, energy price trends.

The aim of this study is to investigate the relevance of an often disregarded aspect: the rate of time preference as an expression of households' behaviours, that is to say, the discount rate adopted within several valuation approaches, which are based on discounted cash flow. Our purpose it to discuss a kind of paradox. The discount rate is commonly estimated in order to take into account uncertainty; nonetheless, the self-same estimation of the discount rate may be a source of additional uncertainty.

2. Literature review

Uncertainty represents a long since well-known issue within the construction and real estate sectors, due to a peculiar production process, which is likely to be more complex and less standardized than other industries [4], hence characterized by fragmentation and discontinuity [5]. A part of recent literature recognized that uncertainty is a main challenge when dealing with retrofit interventions aimed to improve building energy performance [6], because of fluctuating processes involving climate change, government policies, consumers' preferences and technological innovation [7]. Besides, investment in building energy efficiency turns out to be almost irreversible, and this awareness puts more pressure on dealing with an uncertain future [8].

A number of studies found many key variables highly affecting feasibility and success of energy efficiency measures applied in the building sector. The building age is among these variables, although sometimes with a non-linear relationship between energy consumption and construction period [9]. Other relevant variables include savings-investment ratio [10], cost-effectiveness of energy supply [11] and the forthcoming trend of energy supply price [12]. It should be taken into account that the aforementioned parameters exhibit multiple interactions, so as contributing to further increase uncertainty. Meanwhile, surveys conducted during the past years led to argue that stakeholders might perceive investment in energy efficiency as too uncertain, due to high construction or refurbishment costs, ambiguous saving forecasts, unclear maintenance costs and increase of building value still hard to predict [13]. Therefore, households may prefer to delay investment decisions. In other terms, it might be worth to postpone rather than immediately investing in energy efficiency, being the investment characterized by a high option value to waiting [14].

When constructing or retrofitting a building, uncertainty may affect construction as well as running costs, hence planning and design activities have begun to include risk management systems and methods in a life cycle perspective [4, 15]. Appraisal tools based on Discounted Cash Flow (DCF) are set up to handle uncertainty and risk in various ways. Among others, a well-known and widely adopted technique since early pioneering studies [16] relates to the discount rate estimation.

The sum of a base and an additional rate is part of the theoretical background upon which the Capital Asset Pricing Model (CAPM) relies. Indeed, the rationale of CAPM lies in the assumption that the expected return of an investment is expressed by the sum of a risk-free rate and a risk-premium rate, the latter in turn multiplied by a beta parameter, which is estimated in order to cope with the degree of exposure to the non-diversifiable market risk [17]. Accordingly, the model has been recently used to perform quantitative economic analyses in the field of building energy retrofit, wherein conditions of uncertainty entail the need to decide whether to invest immediately or to postpone the decision [6]. Moreover, on the wave of a highly debated issue, relating to the so-called energy efficiency gap [18], CAPM was adopted in the past to appraise the appropriate rate when discounting energy-efficient investments [19, 20].

3. Case study: Overview of Virgolone building within Pilastro district in Bologna

The Pilastro neighbourhood is part of a district named after San Donato, located northeast from the city centre of Bologna (Fig. 1). It is a high-density settlement, mainly composed of public housing. Relying on a council housing plan designed in 1962, construction works started a couple of years later and were carried out by the local public housing authority.

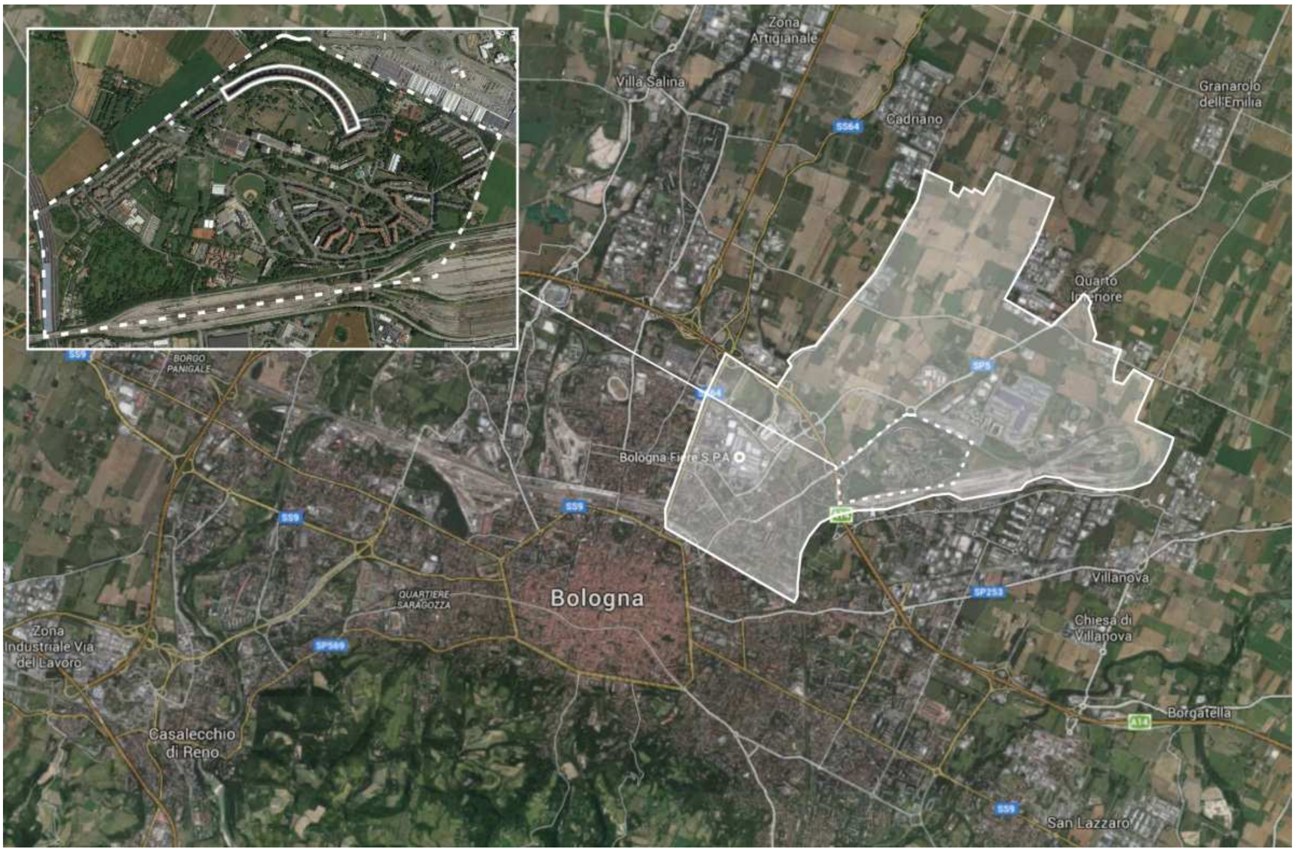

Fig. 1 The city of Bologna with San Donato district (continuous line), Pilastro neighborhood (dotted line) and case study building (continuous line, top left box)

A plan amendment approved in 1975 led to the erection of a peculiar eight-storeyed building, seven hundred meters long. Due to its semi-rounded shape (Fig. 1, top left box), the building is colloquially referred to as “Virgolone”, a slang term which means “big comma”. Construction work lasted from 1975 to 1977. The building was cast-in-place through tunnel form construction technique. It led to erect a reinforced concrete building structure, relying on the systematic repetition of load-bearing partition walls and flat slabs.

4. Retrofit scenarios

Thermal improvement potential of social housing settlement located in the city of Bologna, and particularly in its suburban areas, has been investigated by a number of studies [10, 21].
As far as the case study is concerned, to improve energy performance in comparison to the building as is, seven retrofit scenarios were defined, keeping the structure and arrangement of dwellings as constraints. The first three scenarios concern a better insulation of walls (S1), of horizontal dispersant surfaces such as the ceiling below the roof and the floor above the ground-level ar-

cades (S2), as well as of the whole building envelope (S3). The goal is pursued by means of 14 thickness rock wool panels placed on the exterior. The fourth scenario (S4) focuses on the replacement of windows, by installing double-glazing with low-emission coating and thermal break frame. The fifth scenario (S5) combines the building coating, as in the previous S3 scenario, with window replacement, as in the previous S4 scenario. A new ventilation system, leading to a more satisfactory air exchange rate, is adopted in the sixth scenario (S6). Finally, a further scenario (S7) merges the interventions pertaining to whole building envelope insulation, to the replacement of the windows with double glazing and to the improvement of the ventilation system, as in previous S3, S4 and S6 scenarios. The above description explains that the scenarios lend themselves to be connected in chains, which are suitable to be represented by a kind of tree (Fig. 2).

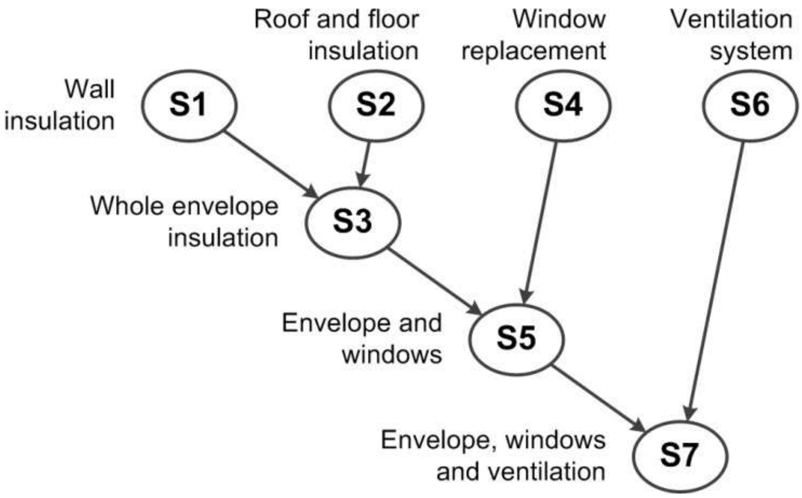

Fig. 2 Scenario's tree

5. Method, assumptions and estimates

To analyse the feasibility of the outlined scenarios, the Discounted Cash Flow approach (DCF) is adopted here. DCF is a widely recognized method, whose introduction into real estate appraisal and property investment valuation dates back to pioneering studies carried out during the mid-sixties and the early seventies [22, 23]. According to the International Valuation Standards, DCF is "A financial modelling technique based on explicit assumptions regarding the prospective income of a business or property" (p. 300) [24].

With regard to analysed cash flows, literature about uncertainty within the building sector distinguishes between internal and external factors affecting projects [13]. The internal ones relate to aspects considered during scheduling and design stages, so under direct control of the participants. As far as the case study is concerned, investment costs depend on decisions of stakeholders about gross floor area of intervention and intensity of retrofit measures; hence, they are classified among internal factors and examined in next paragraph 5.1. External factors are those beyond the project scope, since their source is correlated with the prices of goods and services exchanged within international markets. Within the case study, energy savings are considered mainly an external factor, because they depend on occupant behaviours as well as on the price of energy supply, and they are discussed in following paragraph 5.2.

5.1 Investment costs

All the scenarios previously outlined in section 4 have been applied to a residential block, to which belong thirty flats (Fig. 3). The overall gross floor area under analysis amounts to 1,651 square meters. Investment costs have been estimated through concise sheets relying on the structure of a bill of quantities. Estimates have been performed regardless of savings achievable by implementing the scenarios jointly with other periodic maintenance activities. Costs to supply and installation of the foreseen improvements have been considered together to design costs and expenses due to rental of construction site goods and services, such as equipment and scaffolding (Table 1).

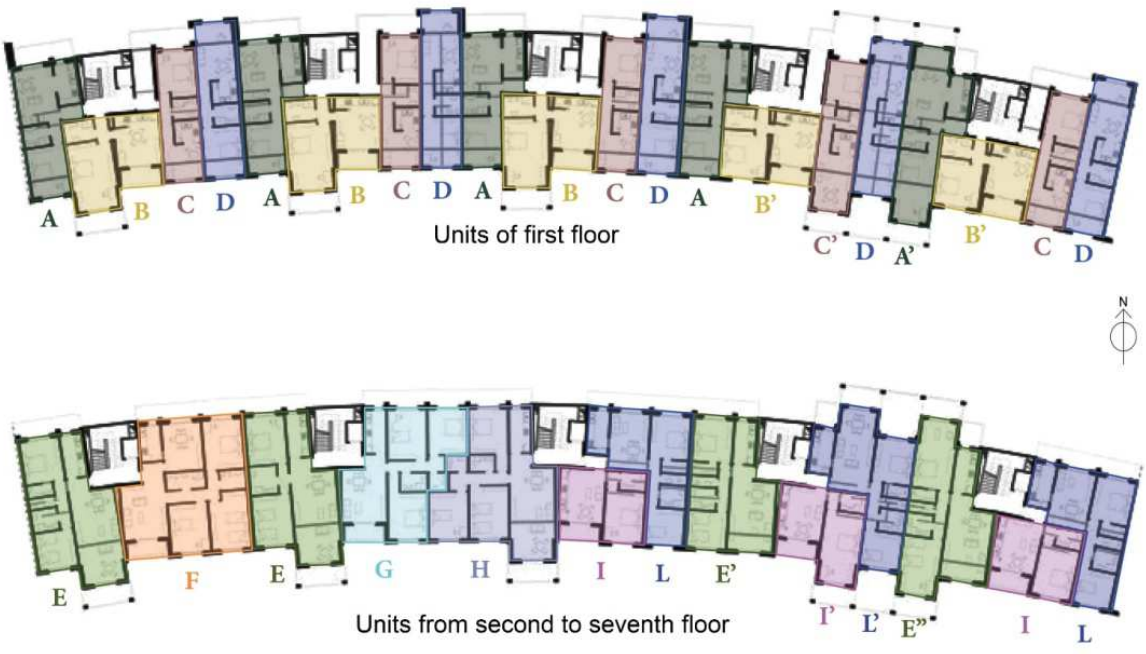

Fig. 3 Plans of the case study, adapted from Copiello and Bonifaci [10], p. 80

5.2 Energy savings

Not only predictable energy consumption, but also data concerning the current energy consumption has been gathered by means of thermal simulation (Table 1), knowing that this could lead to partly biased results. Resorting to simulation models is very usual within building energy analysis, but it is also a source of supplementary uncertainty during scheduling and design stages [13], due to the remarkable amount of parameters to consider and assess [25]. In particular, the accuracy of the model adopted by simulation tools, besides to the building operation practices, is identified as a main factor subject to a margin of error in energy consumption estimates [26].

The software Termolog here used [27] is a package performing a steady-state simulation, allowing to calculate the primary energy need for heating and domestic hot-water production, by means of a procedure which relies on the standard UNI TS 11300 (based on UNI EN ISO 13790) and CEN-Umbrella standards [28]. Not having the opportunity to perform systematic on-site investigations, outcomes of thermal simulation have been compared with consumptions recorded in energy bills on a sampling basis. It has been experienced a rather narrow variance, which is limited to less than 5%.

In order to translate the estimated energy savings in monetary terms, we assume a unit energy price of 0.9 euros/kWh and an energy inflation rate of 4.5% per annum; both the values are consistent with the estimates expounded by a recent study [10].

5.3 Allocation of burdens and benefits among the stakeholders

In Italy, fair rents in public housing and social housing sectors are mainly tenant's income based; nonetheless, the rules governing protected tenancies allow to cover capital expenditures, as established by the legal system of other Western European countries [29]. Besides, social tenants pay energy bills to gas, electricity and water providers. We assume that energy saving allows the tenants to be willing to pay higher rents, although this is a still debated issue in the literature [30, 31]. Because these savings are due to capital improvements on the whole building or on the dwellings, the social landlord - namely the local public housing company - is entitled to cover investment costs by imposing higher rents, hence by capturing the tenants' willingness to pay (Fig. 4).

Table 1: Scenarios, investment costs and energy requirement

Scenarios and energy efficiency measures	Gross floor area *m2*	Unit investment *Euros/m2*	Total investment *Euros*	Energy requirement *kWh/m2 y*	Energy saving *kWh/m2 y*
S0 - Building as is	1,651	0	0	162.6	0
S1 - Building coating: exterior wall insulation made by rock wool panels of 14 cm thickness	1,651	102	168,073	147.3	15.3
S2 - Building coating: insulation of floor and roof made by rock wool panels of 14 cm thickness	1,651	53	87,047	118.3	44.3
S3 - Building coating: insulation of whole building envelope made by rock wool panels of 14 cm thickness	1,651	155	255,121	105.5	57.1
S4 - Windows replacement: double glazing with low-emission coating and thermal break frame	1,651	338	558,675	112.6	50.0
S5 - Building coating as in S3 scenario and window replacement as in S4 scenario	1,651	459	757,928	66.5	96.1
S6 - New ventilation system	1,651	219	361,060	146.4	16.2
S7 - Building coating as in S3 scenario, window replacement as in S4 scenario, new ventilation system as in S6 scenario	1,651	678	1,118,988	49.3	113.3

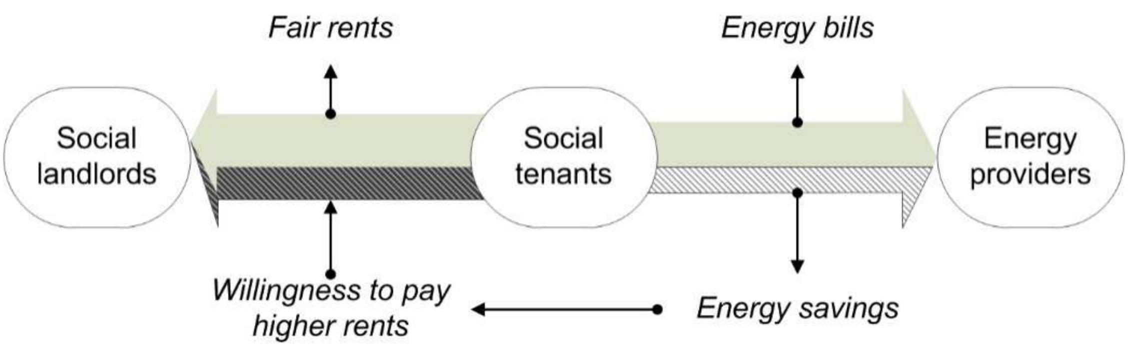

Fig. 4 Allocation of burdens and benefits among the stakeholders

6. Results and discussion

For each scenario, several NPVs have been calculated, by varying the discount rate within the range from zero to 15%. Discount rates adopted by the previously referenced literature are consistent with this range. The study performed by Kumbaroğlu and Madlener [12] suggested a typical value range from 2.25 to 5%, another research developed a sensitivity analysis assuming an expected rate of return ranging from 3.5 to 4% [32], while Nikolaidis et al. [33] appraised net present values and payback periods with discount rates from 4% to 8%. From the perspective of a

household or a public housing company, an ordinary discount rate might lie between 3% and 5% [10], and the same lower level is consistent with the yield rate characterizing the venture philanthropy approach adopted in some recent social housing transactions [30]. Higher discount rate values may be appropriate in order to represent those consumers whose behaviour is driven by a higher rate of time preference [34], or otherwise by upper levels of opportunity cost of capital [35].
A first point worthy to be discussed here concerns the feasibility of hypothesized scenarios. Just the scenario S2 is likely to be economically viable, since the NPV remains positive unless the discount rate is more than 10%. The scenario S3 may be described as characterized by limited viability, because NPV turns out to be positive only when the discount rate is lower than 5%. The scenario S5 is economically viable under the unrealistic condition of a null discount rate, while the NPV swiftly falls below zero if the rate increases. All other scenarios are far from being viable, as witnessed by constantly negative NPVs.
A simple graphic representation brings out the most interesting result: discount rate is set as the independent variable, while NPV is the dependent one (Fig. 5). NPV curves of the seven scenarios show multiple intersections. A total of six reversal points are identified: the first two are recorded for a discount rate close to 1% (points A and B), three other for a discount rate within the range from 2 to 5% (point C, D and E), and the last one for a 10% discount rate (point F).

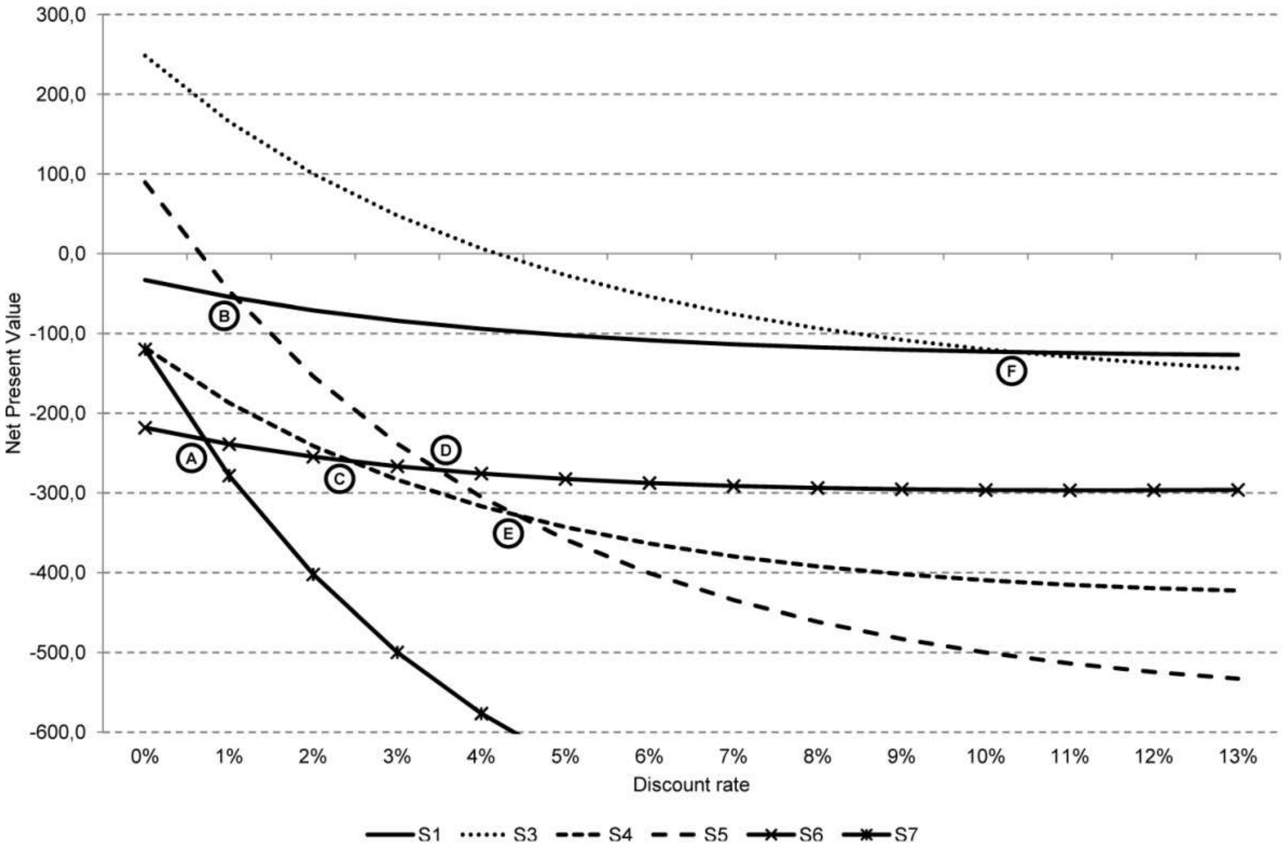

Fig. 5 Reversal points in NPV curves

In the transition from Eq. (1) to Eq. (2) and (3), we experience a major change, since it takes place a complete reversal of the two top alternatives. Despite other minor changes affect the bottom of the rankings, as well as the two other rankings expressed by Eq. (4) and (5), it deserves mention that the top of the rankings may still vary when increasing the discount rate. Indeed, the S3 scenario, which was omitted earlier, shows a reversal point with S1 scenario, corresponding to a 10.5% discount rate.

The diagram in Fig. 5 clearly shows that the NPV curves are characterized by diverging slopes. The reason lies in that the scenarios are at different scales, namely they imply hugely varying savings-to-investment ratios (SIR). Let us consider scenarios S1 and S5. The former is better than the latter when the discount rate is over 1.0% (see point B in Fig. 5), vice versa if the discount rate falls below the same threshold. S5 entails an investment 4.5 times higher than in S1, while the estimated savings are up to 6.3 times higher, but the savings are deferred over time. These are the reasons why the NPV of S5 decreases more swiftly than that of S1.
The achieved results are fairly sensitive to variation in both energy price and inflation rate (Fig. 6). Specifically, assuming a 5% discount rate, in the wake of a 1% decrease in energy price, the NPVs of scenarios S1, S4, S6 and S7 undergo a small reduction of about 1%, while the NPVs of scenarios S2 and S3 are led to a much more intense drop of 4.6 and 18.5%, respectively. A 1% decrease in the energy inflation rate provokes wider swings, up to 22.5% for S2 and 90.7% for S3.

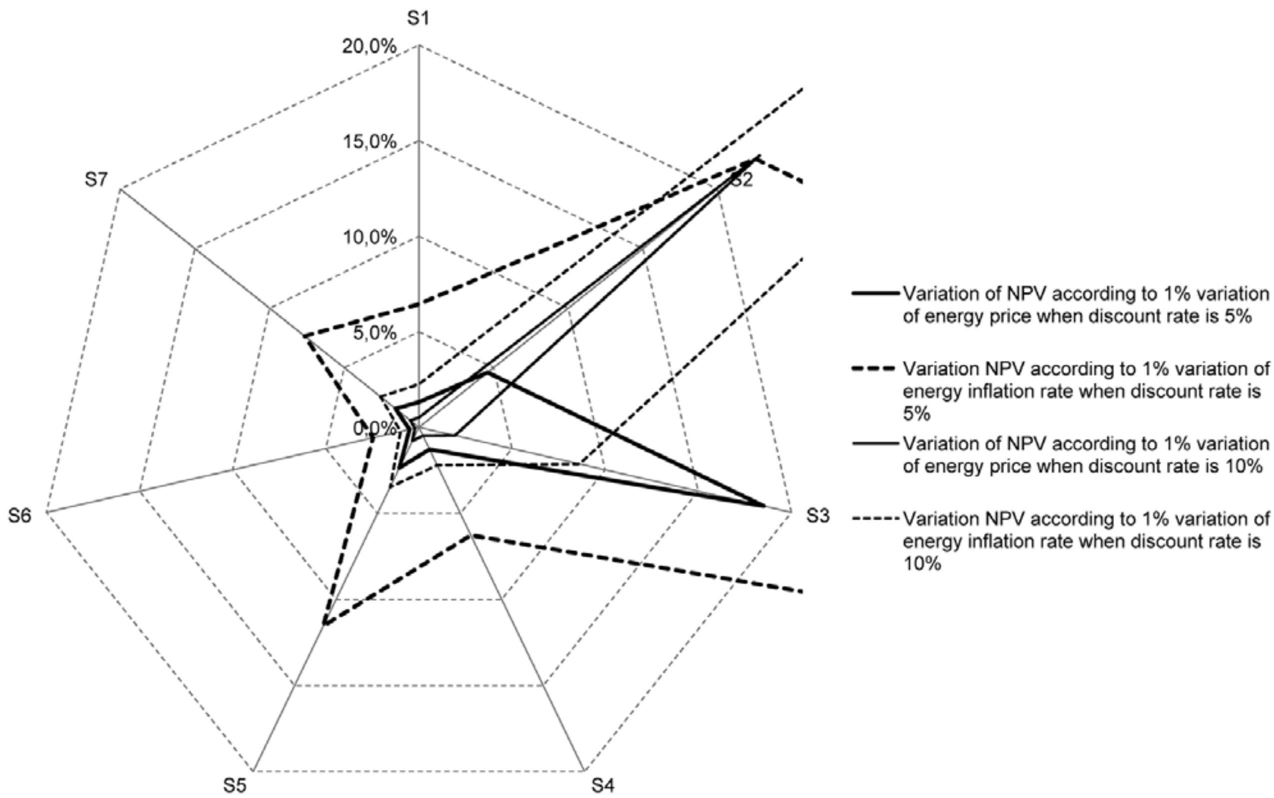

Fig. 6 Sensitivity analysis

7. Conclusions

The analysis performed here suggests that methods usually applied to appraise the feasibility of energy-efficient solutions, such as Discounted Cash Flow and Life-Cycle Cost, should be employed carefully. Since the results are highly sensitive to the several essential variables, the feasibility and cost-effectiveness judgment may be biased by the assumptions and estimates upon a couple of key parameters.
Although, in valuation, the discount rate is considered a useful tool to manage uncertainty, we have shown that it may be a source of irresolute results. This issue is especially relevant in the comparison of efficiency solutions applied to the building sector, because the involved measures are prone to be characterized by different scales in both investment and savings. Moreover, this issue is intrinsic to all the valuation methods based upon discounting, hence it affects not only the Discounted Cash Flow approach, but even the Life-Cycle Cost approach as well as the Cost-Optimal Methodology.

Most of the research previously referenced in the literature review section exhibits one-shot results. On the contrary, only few studies arrange the results within confidence ranges, depending on sensitive variables. Aiming to perform a thorough and comprehensive study, the question discussed so far leads to identify the sensitivity analysis as unavoidable. Further developments of our analysis are identified in the opportunity to carry out extensive sensitivity analyses based on the Monte Carlo simulation method, so to treat simultaneously the variation ranges of energy price, energy inflation rate and discount rate and their correlations.

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BuildNow! – Research and Training

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Summary

At the Luebeck UAS, completely new forms of research in relation with teaching are being embarked on by the Department of Architecture and Civil Engineering: Future teaching staff and students are to try out practical forms of studying so they are able to research innovative building technologies and procedures. The first project is a self-sufficient building which the students plan, design, calculate and build themselves. Renewable energies are used exclusively, therefore energy and water self-sufficiency have been amongst the most important criteria for designing.
You can see if students are involved from the beginning, they learn how to act sustainable for the future.

Keywords: sustainable architecture, self-sufficient building, renewable energies, research in relation with teaching

1. Introduction

Today´s engineering studies have the intention to push students within three to five years to graduate. Subsequently most of the graduees have theoretical knowledge about their majored subject but have to learn many years in practice. Required internships while studying are a first step to guide students from theory to practice, but mostly the time for internships is too short to learn effectively. Furthermore plenty of student apprentices experience that they do not have the chance to really get to know what they are doing: Either they have to do typical intern´s unskilled labours or, especially in engineering offices, have to do their job without really knowing the background. Often, there is no problem at all, because many offices work with standard programmes and also know the common projects.
In construction areas, there are two groups of people: The construction workers who have learnt their specific field. Construction managers, architects and structural engineers mostly have their theoretical ideas but often do not know how to practice them because they have learnt too little application. By reason of the missing communication and knowledge of both sides, new building ideas are blockaded.
The “BuildNow!”-Project wants to “return into the future” by referring on the culture of the stonemason´s workshop and the old master-builders. Precisely, students follow the principle of learning by doing.

2. Methodology

Work from the side huts of medieval ages to constructional master's activities has not known the architect as an exclusive job description. Previously master builders have contrived new ideas and subsequently thought of possibilities to realize them. Nowadays there are many specialists for a building project who have to work in teams without entirely figuring the others problems and intentions.

Therefore "Build Now" pursues a re-innovative or almost new educational approach both for teaching and research.

From the beginning, students learn that they have to plan, design and construct in a very responsible way by themselves.
In contrast to normal lectures where a student only hears about the behaviour of wood, steel and concrete, he really has to internalize. He deals with the behaviour of the materials, compares and matches them. Sometimes students have had an apprenticeship before. Especially carpenters, masons or drywall builders have got a workaday life at building sites as a background. That is very good, but we want to instruct every student to work and think as a master-builder therefore we need a comprehensive and profound practice close to academic studies.
The student will have more impetus and motivation: All along knowing that his constructions will be built, another sense of responsibility rises from the first time he concerns himself with planning and designing.

Moreover students are assisted by their teachers all the time. They will conceive, design and develop together whereby they achieve the best possible results which are much more innovative and sustainable for our future.
These are new ways of research and teaching: The academics are not only a teacher but also adopt the role of lightly guiding mediators.
This point gets very interesting by considering that the economy has to participate as well. Researching might be commendable but for a sustainable effect on the world the economy as well as the industry has to collaborate.
Various enterprises have to be involved at different stages of the project, so at last teachers and students can work in cooperation with the economy.

Nowadays many students know how important sustainability is for the survival of today´s world. They really want to construct and design in an effective and environmentally sustainable way, however either have no idea how to deal with it or are quite simply too unexperienced.
Indeed they see the deep impact of the construction industry on the ecologic environment concerning the climate change and want to arouse this environmental consciousness to a great mass of the population.
In our project, teachers help them to solve this problem: The point is to start at the base and show students of the engineering sciences how to work with it: "BuildNow!" develops a self-sufficient building, completely planned, designed and constructed by students. From the first moment in their job they get in touch to sustainable building and methods.

But not only the involved students benefit from the researches and the development.

This building will be a learing and cultural centre for all students of Luebeck UAS that supplies most of its daily energy requirements through sun, wind and rain. Every student gets in touch with sustainability and learns that he is able to effectuate on prospective lifestyle.

“One of the ideas of the future building” – one miletone on the “new wayof teaching and researching”

The project does not end with the building because students and teachers can research and investigate the behaviour and life expectancy of the used techniques and materials. They will observe and advance.

3. Results

3.1 Responsibility and satisfaction

Primarily, the most important result is the influence of the project on the students. The most sustainable, environmentally sounding and social ideas are bootless if nobody or just a slight percentage is able to implement them.

With the “Build-Now”-Project students get to know these ideas from the very first beginning of their studies and experience them not only as nice and maybe desirable but also as an important necessity for the whole society.

Students often like the easiest way. At the building industry, often just the cheapest way counts. At Luebeck UAS, students get to know the most sustainable way. They are the prospective architects and civil engineers, so if Luebeck UAS generates responsible architects and engineers with the “Build-Now”-project, it generates a new consciousness in the general public.

3.2 Methodology: The journey is the reward

“Build Now” attempts a new method of teaching at Luebeck UAS. The cooperation of teachers and students causes new ideas and, to keep in mind, a better communication particularly between architects and engineers who work together in the project.
Nowadays we have got a more and ore complex world which is very difficult to handle and badly to comprehend. World´s processes change faster and faster every day, consequently the way of thinking has to change as well. With the new methodology we achieve a more appropriate and contemporary teaching and learning.
The journey is the reward: With these fast changes, you never reach a target. The process of constantly searching for the best solutions has to be standard in this day and age. Students get to know exactly this manner at the “Build Now”-project where the best solution never is found: The building itself is not the aim but the path to it a fortiori.

3.3 Increasing the learning outcomes

Usually students have got a basic repertoire after graduating. With “Build now”, they enter into the matter much deeper. Teamwork which is practiced nearly all the time brings much more ideas forward. Everyone understands himself as a member who has to give his best to get the greatest results.
Thus students will have more detailed background after graduating.
The quality of the learning outcomes will not only be increased. Graduees will have learnt how to deal with problems, how to work in teams and how enlarge their know-how, so there is a sustainable success in conveying learning strategies.

3.4 Reducing the gap

In the building sector, there are great gaps between different trades and subsections: Construction workers rarely communicate with office workers, because they often are sure that office workers do not understand real-life problems at building sites. Moreover, civil engineers and architects clash in the majority of cases because of different visions and aims. Finally new theoretical and academic ideas have to be phased with old-established enterprises and economic interests which might be very difficult.
“Build Now” tries to reduce these gaps by involving everyone: Students both of civil engineering and architecture shall work in teams from the beginning. Not only students learn to cooperate this way but the teachers as well. By practicing theoretical ideas by themselves, students combine these academic contents with practical experiences, so real-life is integrated in the processes of learning. This decreases the gap between theory and implementation.
By including various enterprises, the gap between academic and economic interests can be reduced.

With tighter teamwork you can reach a better and faster success and – what is the most important fact – bring the researches of sustainable buildings to all participants of the building sector.

4. Discussion

"BuildNow!" is a project which uses new methodologies and ideas. Consequently, there is no true or false. With every new development and section, we get new information about how to work and more precisely how to improve. This requires a continuous monitoring of past and further steps.
For good results and more effective work, milestones have to be defined: We cannot reach all our goals immediately, moreover we do not want mistakes by rushing the project too fast.
So all team members have to be in constant touch and communication for the best output which means a sustainable way of building.

5. Conclusion

"BuildNow!" achieves a comprehensive contribution to a sustainable future by working at the base. First results of the last years have shown that preparing students for their own healthy lasting future is more than successful: In cooperation with the teachers the students work out very interesting and vibrant new ideas for a sustainable world. Students see that this interdisciplinary planning helps them to imagine their sustainable future by designing buildings, towns and landscapes with new tools and ways of communication. "BuildNow!" furthermore allows students to devolp and improve appropriate tools and shows them how to act responsibly in future life.
Nevertheless, there is a big step to do. The journey is the reward, so "Build Now" never gets to its end, but always will lead students to environmental and social sustainability in a better way. Processes have to be improved and teamwork has to be all-embracing.
Recapitulatory, the "Build Now"-Team is willing to work and research and is full of expectation of the next results.

6. Acknowledgements

The last four years have confirmed our way. A lot of contacts to enterprises have been established.
The first steps for reducing some gaps have been prosperously done and our contacts to thy economy will rise by communicating "Build Now".
Some generations of students already have passed in a satisfied and strengthened way their "Build Now"-period, which means a successful and lasting effect. Now they are able to contribute not only for the "Build Now"-project but for the environment.

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Capturing sustainable housing characteristics through Electronic Building Files: The Australian Experience

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Summary

This paper presents an Australian Government pilot project in 2015 to develop and test a web-based Electronic Building Passport to capture energy efficiency and sustainability related information on residential buildings in the design to hand-over phases of their development and construction. The paper will discuss the key findings of this trial, in terms of (i) local government goals and responsibilities; (ii) available metadata compared with Code required data; (iii) technical benefits and limitations of the online data management system; (iv) data and information sharing, privacy and security; and (v) recommendations for future work.

Keywords: building passport, energy efficiency, information asymmetry, local government, mandatory disclosure

1. Introduction

1.1 European development of building passports

In Europe, the introduction of building passports has been discussed for decades. The primary objective was and is to provide information to a potential purchaser, renter or user of the building. In particular, information asymmetries between the seller/owner on the one hand, and the purchaser/renter/user on the other hand, should be overcome. This is especially important for housing where relevant sustainability features and characteristics may not be easily detected by simple inspection by potential buyers/occupants. Their purchase decisions rely on honest communication of information from the housing supply chain (Blum, 2001; Karl & Orwat, 1999; Lützkendorf & Speer, 2005).

The type, scope and content of building passports or building files have evolved over time and continue to evolve. For example, in Germany, building passports have been a means of *protecting the consumer* by providing a description of the key features and characteristics of a property, a *a quality signal in competition, and an instrument to describe, assess and certify the energetic quality and the environmental and health performance of buildings*. Building passports are increasingly being considered as an important source of information for valuation experts, financiers and insurers (Lützkendorf & Lorenz, 2011). The continuing evolution of the building passport into a tool for communicating diverse characteristics of buildings to multiple stakeholders is evidenced in other European countries such as England and Wales (Planning Portal England and Wales, 2015), Finland (Finnish Green Building Council, 2013; Virta, Hovorka, & Lippo, 2012) and the Netherlands (Klomp, 2006; Van de Bos & Meijer, 2004). The Dutch system, for example, provides a useful framework for what could be considered essential data for a building passport: legal data, status information, quality certificates and functional conditions. In the European Longlife project (Blum & Dirlich, 2010; Dirlich & Blum, 2011) electronic building passports or logbooks were seen as one means of reflecting a life-cycle holistic approach to ecological, economical and social sustainability as well as a multi-level communication system with supporting certification tools.

From these examples of the European experience it is clearly seen that the concept of building passports is continuing to evolve in tasks (content) and scope, as summarised in Table 1. The building passport/building file, however, is only one instrument in a whole system of instruments to support information management and exchange between the main actors in real estate. A deeper understanding of other documentation management instruments, information creation processses and information needs of the various actors over the life of individual buildings, is needed to more closely align each of the instruments to capture the full economic, environmental and societal benefits of building information. This requires ongoing examination of the function and role of building passports within a larger information management, quality assurance and property valuation system.

Table 1 Traditional and evolving 'content' and scope of building passport systems

Traditional building passport system	Building description (building specification) at the time of completion
	Substantive planning documents and planning results
	Substantive planning, design and construction documents
	Substantive building manual and instructions for operation and maintenance
	Quality assurance documentation of project design and implementation
	Proof/demonstration/certification of compliance with quality requirements
Evolving extended building passport system	Continuous provision of documentation over the full life cycle of the building
	Evidence of property service, repair, maintenance and renovation
	Ongoing collection of data on energy consumption, water consumption etc
	Collection of data to be provided to utilities (requirements for energy, power etc)
	Resilience of the building to withstand the future impacts of climate change
	Embodied energy and recoverable materials of the building (e.g. urban mining)
	Data for valuation experts, financiers, insurers etc (inter alia due diligence)
	Data for use by regulators and policy makers

1.2 Australia's housing regulations and documentation

The three levels of government in Australia (federal, state and local) each have different goals and responsibilities in terms of setting regulations relating to dwellings (including sustainability related requirements), the implementation of, and compliance with those regulations, and in documentation processes. Whilst there is a federal National Construction Code (NCC), each state has the right to reject, adopt or amend these Codes to suit their particular circumstances. The practical implementation of the state based codes then becomes the responsibility of each local government authority (LGA) which processes and provides permission and approval for most planning and building activities, and becomes the largest default repository of documentation relating to individual dwellings. Previous research (Miller, Stenton, Worsley, & Wuersching, 2014) revealed that very little of the large amount of data generated for a dwelling over its lifetime is being collated and utilised, bringing into question whether individuals (home owners), the housing industry and society are receiving full benefit from their monetary investment in that information. These findings are supported by the first published report of a current joint state and territory government project, the National Energy Efficient Building Project (NEEBP), that highlighted key systemic, process and attitudinal weaknesses relating to poor performance outcomes and non-compliance with the energy efficiency requirements in the NCC (Harrington, 2014). It found that checking and enforcement of the energy efficiency requirements is very limited, that compliance is likely to be patchy, and that consumers/building occupants know little about the likely, then actual, energy performance of a building. NEEBP found that many stakeholders lack confidence in existing documentation processes in Australia, calling the robustness of the entire quality chain into question. The lack of clear accountability chains, combined with chronically poor information flows resulted in a market situation in which energy efficiency requirements are likely to be systematically under-delivered, at the expense of consumer welfare and environmental quality.

As an outcome of that report, and taking into consideration the evolving nature of building passports from European experience and the ubiquitous nature of electronic data and processes, the NEEBP proposed a small project to examine the potential for an Electronic Building Passport (EBP) to improve the availability of energy efficiency related information to the building industry and market. The aim of the project was to develop and test a web based EBP tool to enable long-term controlled access, management, and use of residential building energy efficiency related documentation and information from the design and assessment phases of residential buildings.

2. Methodology

2.1 Participants

The EBP trial design was approached from the knowledge that LGAs are the single largest repositories of individual building data (legal, status, quality and function) due to their role in processing and approving building applications. The project sought to determine the extent to which an EBP could be founded on these large document stores and integrated into existing processes. From the thirty LGAs invited to participate in the project, eleven LGAs (from all six Australian states) volunteered to participate in tool development and testing. A further fourteen LGAs, unable to actively participate in the project, joined the EBP community of interest for ongoing dialogue.

2.2 Documentation of existing practice

A multi-pronged approach was utilised to document existing practice relating to residential building information. First, the NCC was examined to determine what documentary evidence was expected to be provided as part of the building approvals process in general and in terms of energy efficiency requirements specifically. The purpose of this step was to determine the regulatory expectations (explicit or implied) of building information. Second, the building approvals processes of each state were examined by collating information provided on local and state government websites relating to housing construction. The purpose of this step was to identify similarities and differences between states, and between the states and the NCC expectations. Third, the building documentation practices of participating LGAs were examined through their respective websites. This included examination of processes, systems and format for document collection; data management and accessibility; chain of responsibility; and content (what information is collected and in what format). This comparison of processes within each state and LGA jurisdiction was checked and amended by discussion with local government participants in a one day workshop.

The two requirements of the trial EBP were to (i) capture the building energy efficiency data (i.e. extract the data from existing documentation to enable it to be part of a searchable database) and (ii) capture the NCC related documents that could act as 'proof of quality' or 'proof of compliance'. The trial tool needed to be low cost, user friendly (i.e. require minimal training) and accessible to geographically dispersed organisations. This limited scope was seen as the starting point or minimum requirement of an EBP that could be expanded to capture broader sustainability related information in response to future regulatory or market drivers.

2.3 Tool Development and Testing

An open source data management platform designed to make data broadly available to multiple stakeholders, was adopted as the platform for the EBP tool as it enabled the project to test the concept of an EBP without requiring large investment in commercial software and without jeopardising existing data systems of participating councils. CKAN (http://ckan.org) is used by organisations, cities, states and countries around the world, including in Australia (e.g. http://data.gov.au and https://data.sa.gov.au/).The tool enables users to create organisations (e.g. an LGA) who then create datasets (all information, files and links related to a single dwelling). Each dataset can act as the passport for a building and contains data fields (metadata) and data sources (uploaded files in any format). Data fields were deliberately restricted to only incorporate property identifiers and the data typically recorded on the energy certificate or alternative document that is meant to accompany each building application: property identifiers (5 fields); building type and stage identifiers (6 fields); climate zone (1 field); space heating and cooling loads as designed (4 fields); elements to impact thermal performance (12 fields); conditioned/unconditioned floor area (2 fields); water heating, space conditioning, lighting, swimming pool (5 fields); Infrastructure connections (2 fields), onsite photovoltaics and storage (2 fields) and data status (3 fields). This selection of data fields was premised on the understanding that LGAs could be involved in providing the foundations of an EBP that could, at a later stage, be expanded to include other datafields (e.g. thermal comfort, EPCs, base load power, peak demand etc), other data providers (e.g. occupants, building managers, utilities, sustainability assessors etc) and other data users. EBP V1.1 did not predetermine the amount or type of information held in datasets. The only mandatory steps were the manual entry of the building's address and the upload of a single file or link to information held elsewhere. The creation of each dataset reportedly took twenty - thirty minutes.

3. Results

3.1 Building approval processes and documentation

A typical building application lodgement process in LGAs requires the completion of an online (or paper based) application form and submission of accompanying documents. The application form contains the data fields that are automatically or manually entered into the LGAs' existing data management systems. Analysis of LGA processes revealed that only generic property metadata is currently collected (e.g. descriptions of the land, applicant, owner, certifier) along with mandated building specific information required by the Australian Bureau of Statistics (ABS): the nature of building work, number of storeys, gross floor area, number of dwellings and occupancy (number of families per dwelling). Until 2013 the ABS also required LGAs to report on building materials used for the roof, wall and frame. It does not appear that LGAs use the data they collect for the ABS.

The NCC does not specify what types of documents would provide ‘proof of compliance’ with the energy performance requirements of the Code however it does specify that decisions made under the NCC should be fully documented and that all relevant documentation should be retained. This would imply that the State, and by default their respective LGAs, have this responsibility. This is interpreted by different States and LGAs in various ways, with some jurisdictions providing clear guidance on documentary requirements for building approvals, whilst others leave it up to the building applicant to provide ‘supporting documents’. Whilst all LGAs provided some guidance for information that is required to support building applications (e.g. building and site plans, soil tests, structural engineering certificate, structural engineering report etc), none of the LGAs requested, collected or stored documentary evidence supporting all of the energy efficiency requirements of the NCC at the building application stage. Even less guidance is provided to LGA inspectors or private certifiers who have the role of determining if buildings have been constructed as designed.

3.2 Observations from EBP datasets

A comparison was made between the LGA datasets in the EBP and the documentation required by the NCC. The majority of information requested by the data fields should be available on the application form or energy certificate and/or on the building plans that accompany a building application. Initial examination of the metadata (individual data fields) shows that:

- Construction materials (roof, walls, floor) data fields were generally completed but approximately half of the data sets did not indicate roof absorptance or roof insulation.
- Ceiling/wall insulation type and R value was missing from 20% of data sets.
- Glazing was generally known but was mostly described in unspecific language (e.g. single clear or single tint). Only 4 data sets specified U and SHGC values.
- 77% of data sets had no metadata on number of ceiling penetrations; 40% had no metadata about the hot water system; 59% had no metadata about the lighting efficiency.

The supporting documents attached to each data set were then examined, comparing lodged documents with the NCC documentation requirements (Table 4).

Table 2 Comparison of NCC document requirements and EBP dataset

Documents required by NCC	**Comments on documents in EBP dataset**
Building and allotment plans, drawings and specifications	55% of data sets did not contain any building specific documentation. The remainder contained standard design drawings. One data set contained a floor plan only.
Energy certificate (thermal envelope) or details or tests and calculations to prove compliance	67% of data sets had an energy certificate or alternative report attached (for ‘as designed’)
Certification and expert signoff for air movement, building sealing, glazing, hot water type and efficiency, building insulation, insulation of service pipes, lighting efficiency	None provided
Certification that plans meet Code	None provided

4. Discussion

The following section discusses the four main issues that arise from these results and suggests areas for future research.

4.1 Local government goals and responsibilities

By far the most important issue raised in this trial project was one of goals and responsibilities regarding building information. One of the purposes of the project was to assess the extent to which LGAs are currently utilising the documentation requirements of the NCC to help deliver the Code's energy performance requirements. As mentioned above, however, the study found that none of the LGAs are currently collecting all of the energy efficiency related documents required to assess compliance of buildings 'as designed' and 'as constructed'. The key reasons for this appear to be the distinct lack of clarity in the NCC regarding what specific documentation is required and no guidance on who is required to provide, collect, evaluate and store that documentation. LGAs appear to think of themselves as passive libraries or warehouses of building documentation, with no responsibility or warranty given for ensuring the completeness or accuracy of the information. At least one State actively discourages LGAs from requiring documentation, due to perceptions that this was unnecessary 'red tape', yet the State also doesn't take responsibility because they don't process building applications. This lack of clarity and accountability in the regulations, combined with limited LGA resources to meet all community demands at the local level, has resulted in LGAs taking a pragmatic, risk management approach to building documentation. The argument appears to be that (i) consumer demand for documentation relating to building energy performance is low, and that (ii) non-compliance with the full documentation requirements represents a relatively low risk to LGAs and their communities. The overall impression is that energy efficiency information about individual dwellings has no value. (This is the starting point for further work to overcome such barriers, as briefly discussed in section 4.5.5.)

Having said this, the participating LGAs agreed that an EBP could play an important role in improving documentation and information processes and hence the compliance rates and energy productivity of housing. The majority felt that such a system would only be taken up if it were

- A nationally agreed system, imposed as a mandatory requirement;
- Capable of being used by multiple stakeholders, particularly LGAs, private certifiers, building regulators, builders and energy assessors; and
- Fully integrated into, or seamlessly compatible with, their existing document systems.

4.2 Metadata and data source analysis

The metadata (data field) and data source analysis (section 3.2) suggests that councils do not see a need for, or value in, capturing building specific metadata through their lodgement process. Analysis of their existing processes however (section 3.1), reveals that LGA lodgement systems can capture metadata beyond their own data needs (e.g. ABS data) when they are required by a higher authority. This supports the perception of participating LGAs that a nationally mandated EBP may be possible. The results also indicate that the information contained within documents is not being fully utilised. Electronic files (e.g. PDFs, jpeg etc) are being stored but their content is typically not accessed or converted to a searchable form. This is similar to some European Energy Performance Certificate (EPC) databases where the documents are captured but the information is not (e.g. Romania). In contrast, advanced EPC databases, such as those of Hungary and Portugal, are capturing all EPC data in searchable databases (Arcipowska, 2014).

4.3 Technical benefits and limitations of online data management

The pace of development of information technology and communication methods has far outstripped the pace of development of regulatory compliance and document and information management systems. As a result, both regulatory compliance and market systems within the housing industry are typically not taking advantage of readily available, even ubiquitous technologies such as smart phones and mobile devices with their related apps, cloud-based data systems and advanced data analysis processes. The full value of the information that is currently being paid for is not being captured and the current system exhibits unnecessary costs and duplication of processes. One could argue that to realise the full value of building data, the information has to be accessible, reasonably complete and accurate, in an understandable format for the intended user, and delivered at a low cost. The benefits of a well-designed and implemented EBP potentially include:

- Faster lodgement, processing and retrieval times and therefore reduced costs
- Improved documentation accountability through standard-form lodgement templates
- Rapid and low cost inspections and audits (verification of performance as constructed)
- Facilitation of quality certification, voluntary disclosure and best practice initiatives
- Improved national consistency and reduced regulatory uncertainty and compliance costs
- Expansion beyond an energy focus (e.g. health, amenity, safety, resilience, accessibility)
- Improved statistical information for policy and program development and assessment

A number of barriers to the implementation of a national EBP in Australia were also voiced, such as concern over duplication of existing efforts, additional costs (e.g. data entry) and the overall cost of such a system (e.g. software licensing, development and training). To capture the benefits and overcome the barriers, it is important to clearly define the type of information such a system would want/need to manage. Based on the evolution of the building passport concept in Europe, one could argue that a well developed building passport system would provide six key types of information, at different levels, for different users (Table 5).

Table 3 EBP information types, levels and users

Information type	Information level of detail	Information Users
Building Description	Technical detail (e.g. complete planning documents) and in an easily understood format that describes essential features and characteristics to purchasers/users	Individual building level: for use by owners, investors, occupants, managers
Operating instructions / manual	The building users require information and instructions for proper use, operation, maintenance/servicing and repair (at a technical level and easily understood format, depending on nature of the building)	
Quality Certificates	Assessment results from neutral third parties	
Life cycle information	Renovation / reconstruction information; consumption data; repairs and maintenance log	
Third party information	Information on relevant individual building-related characteristics and features e.g. physical characteristics, the actual performance, as well as the sustainability and robustness of the buildings	Evaluation experts and appraisers; financiers; insurers; real estate agents
Portfolio and statistical data	Information on collections of buildings (e.g. portfolios) or regional / state / country building stock	Countries, regions, LGAs, researchers

4.4 Data and information sharing, privacy and security

In Australia, the identified regulatory and market weaknesses have national significance, impacting on national policy goals for energy efficiency and greenhouse gas abatement. At an individual and societal level, consumers are likely buying/renting and occupying homes of lower quality, in terms of energy performance, than they anticipate. An EBP could not solve all these issues in isolation, however it could ensure greater access to relevant building information, creating a greater opportunity for accountabiity throughout the building supply chain, and for all parties. Whilst the importance of data was recognised, one of the key issues raised by LGA participants in this trial was that of privacy. The two sub-texts here appeared to be (i) what information is considered to be private and (ii) who should be granted access to different levels of information. These differences were attributed to the conservative, risk averse nature of government organisations processing requests for access to information and the lack of training and detailed familiarity with legal requirements regarding privacy. Whilst this is a global problem, some countries appear to be managing the privacy issue. For example the Dutch EPC data base gives access to individual EPCs (searchable by number, postcode and address) and public access to aggregate EPC statistics. Similarly Denmark has implemented a multi-layer access system to their EPC data base, with different levels of information available to different users (Arcipowska, 2014).

4.5 Recommendations for future work

This discussion leads to the identification of four areas where further research may be beneficial.

4.5.1 The other side of the privacy debate

What is often not mentioned in the information privacy debate is the other side of the coin: the consumers' right to information and product disclosure. In addition to general safety and performance information available for most consumer goods, many household products are purchased with quite detailed energy performance information: food, large appliances, cars and even smart phones are examples of these. In comparison, information provided about a dwelling is very limited. It is conceivable that learnings from policy and market research for other consumer goods could be applied to the building sector.

4.5.2 A hybrid mandatory and voluntary EBP

The introduction of building passports has been discussed for decades as either a voluntary instrument or as a form of information obligation toward buyers and renters. Their mandatory introduction in the form of information obligations, as well as the mandatory requirements on the structure and content of building passports, have not been successful so far. Perhaps this project has shown that there is a need to examine a potential hybrid form of building passport, where existing building approval processes become the foundation of the file (mandatory), which is then contributed to, in voluntary and mandatory forms, over the life of the building, by various parties.

4.5.3 Development of a benefit:cost analysis of national building databases

Any Electronic Building Passport, whether at a municipal, state or national level, will require investment of time and money. To be successful, and to avoid the 'bureaucratic burden' label, such an investment needs to be balanced against quantifiable evidence of the economic, environmental and social benefits of such a data base. Learnings from a number of European EPC data bases could be shared to build this evidence. For example, how are EPC databases currently being used to justify large scale investments in energy efficiency programs (Netherlands), monitor on-the-ground retrofit activities (Portugal), map the housing stock (Scotland, Netherlands), and understand policy impacts, progress and challenges (Arcipowska, 2014). Other potential benefits that need further quantification may include risk reduction (e.g. for building owners, managers), time and cost savings for third party users of the information (e.g. valuers, financiers, insurers, real estate agents) and public benefit (e.g. consumer protection, environmental and health protection, resource management, crisis management etc).

4.5.4 Clear identification of the tasks and functionality of an EBP

Operationally an EBP must be clearly defined in order to design the appropriate infrastructure. Issues to be considered include (i) specific tasks to be incorporated; (ii) the division of labour and sharing of functions with other instruments; (iii) the demand for the information from other market participants and the nature of the information they require; (iv) how multiple parties can contribute to the information; and (v) data integrity.

4.5.5 Future work on the Australian EBP trial

Overall we conclude from this pilot that the public good would be well served if the Australian and state governments continued to develop and implement an EBP system in a cost-efficient and effective manner. This development should occur with detailed input from building regulators, the Australian Building Codes Board, LGAs and private certifiers in the first instance. A recommendation to this effect has been made to the relevant authorities. In the meantime, the community of practice has access to the trial EBP, and the Queensland University of Technology is extending the current work by trialling the conversion of housing data into gis format to contribute to the spatial mapping of one particular LGA, comparing energy efficiency data in this LGA with real estate sales data, and examining how the an can be a source of information for economic valuation.

5. Conclusion

This paper has outlined the methodology and initial results of a small trial EBP in Australia, discussed the main issues arising from the trial, and proposed further areas of research. The key message from the Australian experience is that a large volume of information is generated about an individual dwelling over its lifetime and that society is not capturing the full benefits of their investment in this information. In order to create a low cost documentation system for individual dwellings there is a need to collect data at the time it is created by the various stakeholders - from the design phase, through the construction phase and into the operational phase. The actors involved in different stages of the building need to be educated to respect the information needs of other stakeholders, and the system needs to be flexible enough to provide usable information to both the consumer and experts. Electronic Building Passports play an important role in such a system and the exchange of ideas, practices and project analysis between Australia, Europe and other parts of the world is beneficial in the ongoing development of such an instrument.

6. Acknowledgements

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Carbon storage and CO_2 substitution in new buildings

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Summary

Comparing conventional constructed buildings that contain numerous construction products derived from finite resources with buildings with a high proportion of building products derived from renewable raw materials shows a significant ecosystem load reduction potentials offered by the latter construction method.
The carbon storage for the "standard version" reaches only 1 to 6 kilogramm per m² GFA. The buildings with a high quotient of renewable materials reach 45 to 87 kilogramm C per m² GFA.

Keywords: carbon storage, CO_2 subtitution, wood, life cycle assessment

1. Introduction

"For a long time, the science of construction materials confined itself to enumerating the material, physical and chemical properties of construction materials, without taking into account their impact on health and comfort or on environmental pollution and other ecological issues.
Whereas previous approaches only measured and tried to minimise the direct and localised consequences of manufacturing or utilisation processes, the eco-balance method aims to take into account - and to reduce - problems transferred to other locations or to other environmental media".

With the knowledge, that there will be sooner or later a lack of resources [1], a period started to save energy primarily in the building sector. There also is the goal in the European Union that up to 2020 new buildings will have no consumption of energy during the use phase. Following this, the ecobalance of buildings, which is until now dominated by the energy consumption during the use phase e.g. of 50 years, will bring the building products in the foreground. Because wood and construction products derived from wood contain carbon in a bound state, a building constructed from wood products can also be described as carbon or carbon dioxid store. Renewable natural resources have a low negative impact on the environment thanks to low primary energy expenditure and low greenhouse gas output during their manufacture phase. The carbon accumulated during the growth phase– which is documented in a carbon dioxide credit note – is cancelled out during the disposal phase of the construction components.

2012 was decided in Durban to prolong the Kyoto-Protocol for the protection of the climate and introduced rules for the methods and calculation of the national CO_2-Balance of the forests.
Also in this year, the Federal Environmental Agency of Germany (UBA) declared that more than 25 million tons CO_2 are bound every year in the growing national forest stock [2]. Therefore, it will

be important to have exact figures about the content of wood and wood-based products in the existing building stock. Taking into account the changing methodologies in the construction sector, it will be important to calculate the influence of several material-mixes on the future state-of-the-art.

The Intergovernmental Panel on Climate Change (IPCC) has published a list with reference data of the carbon storage capacity in wood and wood based products [3]. Based on these assumptions, it will be possible to calculate the exact carbon storage during the reference service life of the building. These data build the base for the calculation of the existing carbon storage of the national building stock. The research project „Active climate protection by resource efficiency of wooden buildings“ [4] should deliver data for different materialspecific solutions in the building sector. The results of this research project are presented here.

2. Methodology

Since 2009 three certification systems for buildings have been established in Germany: The federal certification system (Bewertungssystem Nachhaltiges Bauen für Bundesgebäude - BNB), the private certification system (Deutsche Gütesiegel Nachhaltiges Bauen – DGNB) and the private certificate of the union of the housing industry (Gütesiegel Nachhaltiger Wohnungsbau – NaWoh). All systems require that a life cycle assessment is carried out under the “ecologic quality section”. This assessment takes into account both, the resource consumption and environmental impact of contructing as well as operating buildings. An evaluation of the environmental impact of all the materials used is a significant part of the life cycle assessment. Different materials, construction products or building plans can be assessed by comparing data on properties of materials, their durability, the frequency of maintenance required and dismantling options. To help people make these calculations, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit, BMUB) maintains a public database of life cycle assessment modules known as Ökobau.dat. Since 2009 there have been three versions published. The life cycle assessments shown here were compiled using information taken from the Ökobau.dat 2011 database. 2011 the database was not yet in line with the new EN 15804 and EN 15978. In the previous database for the End of Life phase (EOL) was only one set of data, combining the modul “C1-C4 dismantling and disposal” and modul “D benefits of recycling potentials”. Construction products with a heating value are thermally utilised through combustion, including the production of electricity through heat-power cogeneration. Metals receive a bonus for their recycling potential.

The LEGEP software tool was used to model and calculate values for the objects. LEGEP is a tool for integrated life-cycle analysis resulting from basic research in Germany, Switzerland and France. It supports the planning teams in design, construction, quantity surveying and evaluation of new or existing buildings or building products. The LEGEP database contains the description of all elements of a building (based on the German DIN 276 standard, which can be mapped to other similar standards); their life cycle costs (LCC/WLC based on the German DIN 18960 and the final report EU-TG4 LCC in Construction). All information is structured along life cycle phases (construction, maintenance, operation, cleaning, refurbishment and demolition). LEGEP establishes the following issues simultaneously and for the whole life cycle

- the energy demands for heating, hot domestic water, electricity (according to the German standard EnEV 2014, DIN 18599 and EN 832)
- the building construction, operation (energy, cleaning etc.), maintenance, refurbishment and demolition costs taking into account the EN 16627

- the environmental impact (effect oriented evaluation ISO 14040ff.), and resource consumption (detailed material input and waste) based on the Ökobau.dat 2015, taking into account the DIN EN 15804 and DIN EN 15978.
- Comfort and health risks regarding indoor climate by means of product substances based on the documentation rules of REACH and EU regulations.

LEGEP is organised along four software elements with their own database. The method is based on cost planning by "elements". The database is hierarchically organised, starting with the Life Cycle Inventory (LCI)-data at the bottom, building material data, work-process description, simple building elements for material layers, assembly building elements like walls, and ends with macro-elements like building objects. Each construction element (new or refurbishment) triggers its own life cycle elements (operation, maintenance etc. with their specific periodicity and intensity). The data are fully scaleable and can be used either "bottom-up" or "top-down".
For the research project eight buildings with many components containing renewable natural raw materials have been chosen.

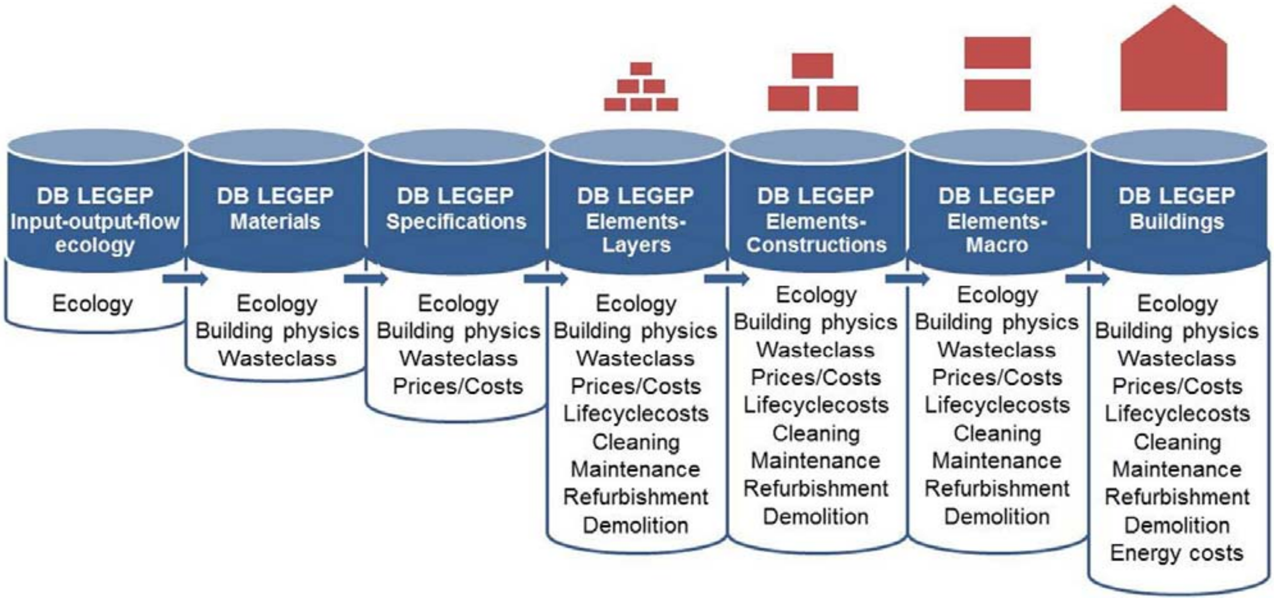


Fig. 1 Hierarchical organization of data " Staircase" in LEGEP database.

The aim was to supplement the physical building model with a digital information model, which exactly describes the manufacture of all components and calculates all the quantities involved. For each building, a "standard version" building constructed using conventional construction products – largely created from non-renewable mineral, metallic or synthetic materials – was also modelled. The "standard version" building is identical to the real building in terms of space, floor area and shape, and therefore has the same energy requirements. The building´s energy demand is not taken into account, as the key energy demand performance indicators are constant for the assessed real building and the "standard version" building. The components were taken from the catalogue of elements in the LEGEP databank; their construction and materials correspond to many buildings that have already been life cycled assessed. The modelling of these "dizygotic twins" reveals the differences made by changing the construction type.

Table 1 shows the different size, volume and number of levels of the chosen objects. The construction year of the new built buildings range from 2005 – 2013.

Table 1: Assessed buildings, volume and space

Buildings	Architect	Year of construction	Level	Gross floor area (m²)	Net Floor area (m²)	Volume (m³)
Industrial Building Lindenberg	Lichtblau Architekten	2005	2	5247	4623	25160
Tax Authority Building Garmisch	Bauer	2011	2	4835	4318	17640
Community Center Ludesch	Kaufmann	2005	3	2064	1811	5895
Residential Building Samer Mösl	Dietrich /Untertrifaller	2006	3	6152	4950	19072
University Kuchl	Sps-Architekten	2009	3	1474	1209	5782
Residential Building Munich	Kaufmann-Lichtblau	2011	4	1257	1039	3876
Residential Building Erlangen	Gewobau, B&O	2013	6	1394	1168	3965
Youth Center, Munich	Lichtblau	2009	2	642	563	1743

The life cycle assessment evaluations deals with the part of the buildings which begins at the underside of the ground storey´s floor slab; any cellars and special foundations, such as piles (necessary due to bad load bearing capacity of the ground) are not included in the calculation. These parts can have a significant influence on the results, but they are a specific singular solution and can not be generalized.
The study confined itself to buildings with a wooden main loadbearing construction. Where renewable materials are only used in isolated areas of the building – e.g. the façade, the floor or the roof insulation – the life cycle assessment remains significantly the same as for a conventional building, because the volume and therefore the weight of renewable material used is too small to show a significant impact. Therefore, the primary construction – the loadbearing components of the external and internal walls, the ceilings and the roof – is made of wood or of wood-derived products. Only objects following this construction rule show significant differences to the “standard version”.

3. Results

The following graphics compare all the analysed buildings. The reference size value for the weight is one square metre of gross floor area (GFA) and for the life cycle assessment (LCA) is the same as used for the certification systems: one square metre of net floor area (NFA) per year. The building - without energy demand - is evaluated over a base period of 50 years, factoring in the phases of production, refurbishment and disposal. During this lifecycle the building parts with a lower lifetime are removed and substituted by new components. The period used for the refurbishment follows the “Useful Lives of Construction Parts” declared by the German Federal Building Ministry.

3.1 Choice of materials and weight

The results show clearly that the buildings constructed from renewable raw materials weigh only

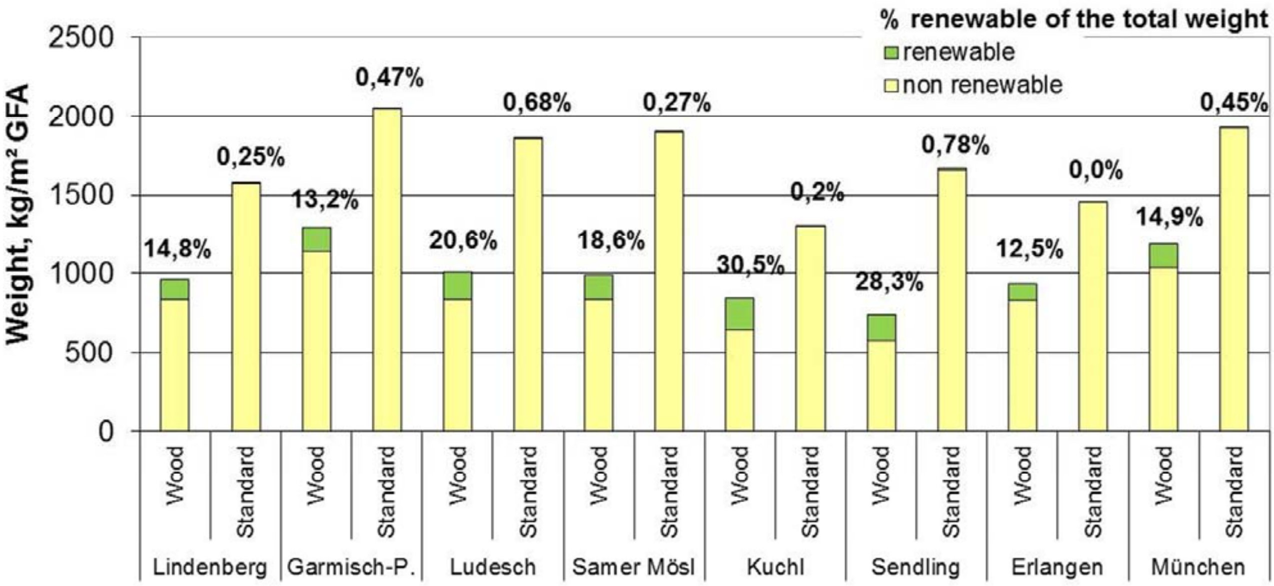


Fig. 2 Material requirements for production and refurbishment, 50 years, kg/m²GFA

50 - 65 % of what conventional equivalents weigh, with kg as the unit of weight. They also show that conventional construction methods use a very low proportion of renewable raw materials, ranging from 0.2-0.78 % of the building´s overall weight. In buildings with a high proportion of renewable raw materials they account from 12 to 30 % of the building´s overall weight (Fig.2). The fact, that this figure is low despite the structures consisting almost entirely of wood, is due to the high weight of the mineral construction parts. The groundfloor slabs of the wooden structure which are made of concrete, weigh as much as two wooden ceilings with floor construction. Most of the buildings featured in this study are two-storey buildings. Where wooden buildings have several storeys, the impact of the mineral concrete floor slab is balanced out.

3.2 Life cycle assessment

A building´s life cycle assessment consists of two elements: an energy and materials flow balance that documents the origins of all resources used (including a bill of materials) and primary energy (renewable and non-renewable) and an impact assessment. The impact assessment is based on several indicators: Global Warming Potential (GWP), Abiotic Depletion Potential (ADP), Ozone Depletion Potential (ODP), Photochemical Ozone Creation Potential (POCP), Acidification Potential (AP), Eutrophication Potential (EP). Each indicator relates to a different set of problems. Therefore it is not surprising if readings do not show a linear progression: that is, if a building type does not receive similarily good marks in all areas. The results of four indicators are documented here. No assumption was made for the energy mix variation, which will change within the next fifty years. The comparison is based on the current energy mix.

3.2.1 Primary energy

The indicator "primary energy" is separated in non-renewable and renewable. Non-renewable primary energy consumption is the sum of overall finite abiotic energy resource expenditure, such as hard coal and lignite, mineral oil, natural gas and uranium. All wooden buildings have lower primary energy non renewable values than the "standard version" building by somewhere between nineteen to sixty-seven per cent (Fig.3).

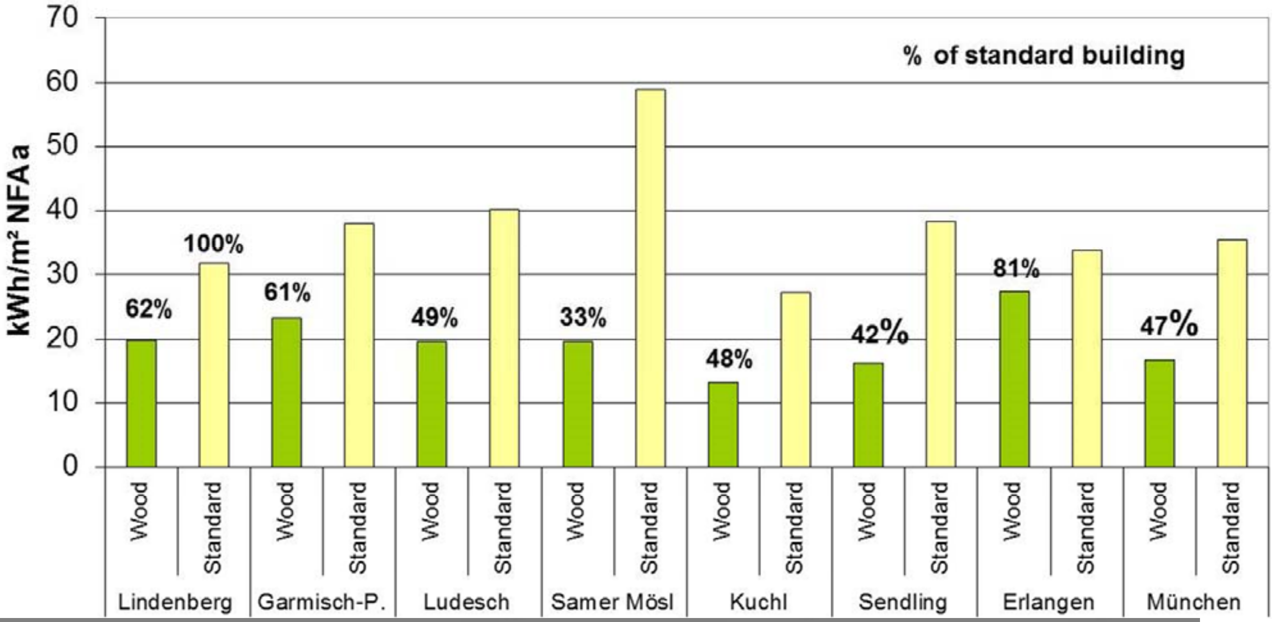


Fig. 3 PE non renewable, only building, 50 years, kWh/m²NFA a

The building´s renewable primary energy consumption consists of the energy contained within the building in terms of biomass, water power, wind power, solar energy and geothermal energy.
All buildings with a higher renewable construction materials quotient also have a higher primary energy quotient: five to eight times higher than that of conventionally constructed buildings.

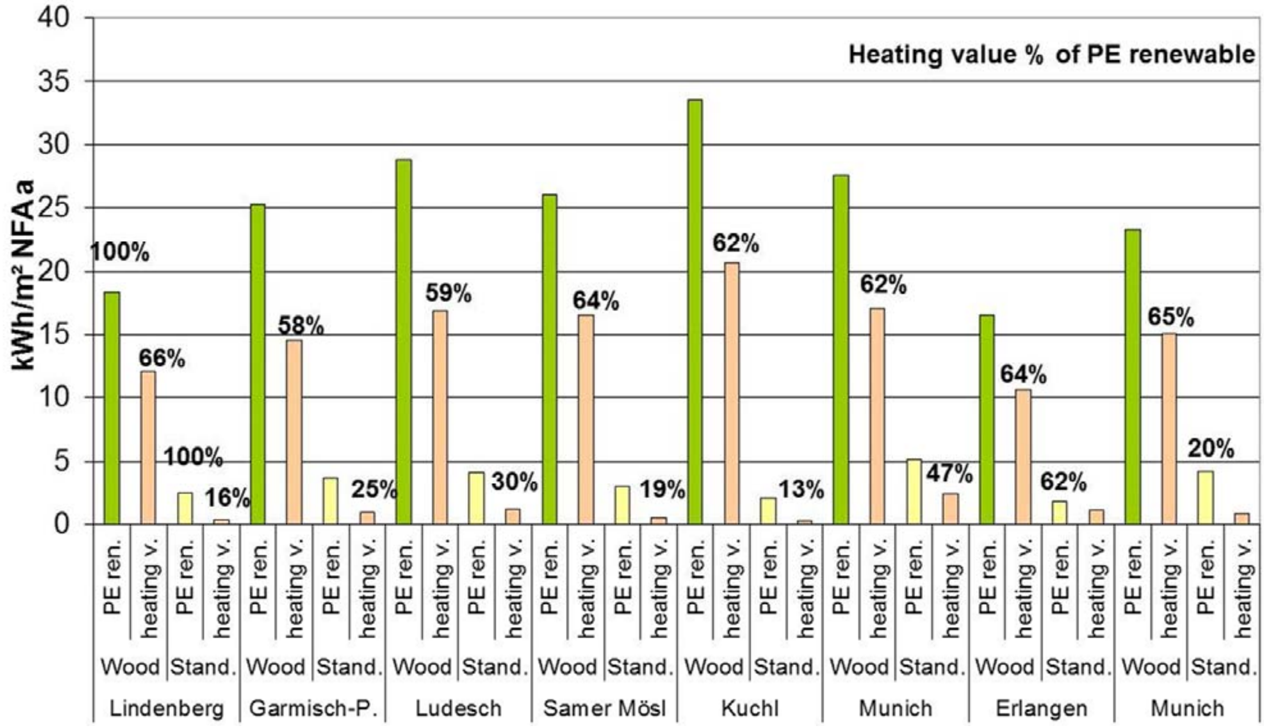


Fig. 4 PE renewable and heating value, building, 50 years, kWh/m² NFA a

This high percentage of renewable primary energy results from the heating value contained in renewable raw materials (shown separately in the Figure 4). Without the calorific value of the wood the renewable primary energy quotient is two to four times higher.

3.2.2 Global warming potential

The scenario for the calculation of the indicator global warming potential (GWP) includes an end of life scenario (EOL) where the components containing stored carbon will be thermally utilized. The buildings with a high renewable construction materials quotient show reduction potentials of 31 to 74 percent compared with the "standard version" buildings (Fig. 5).

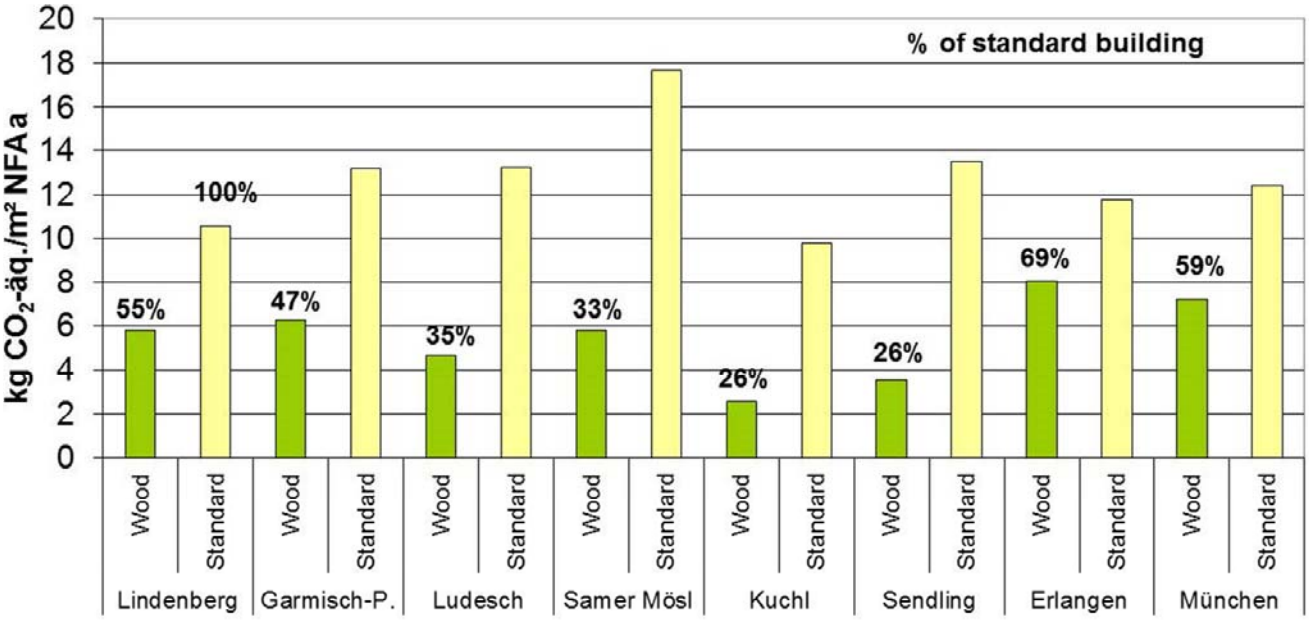
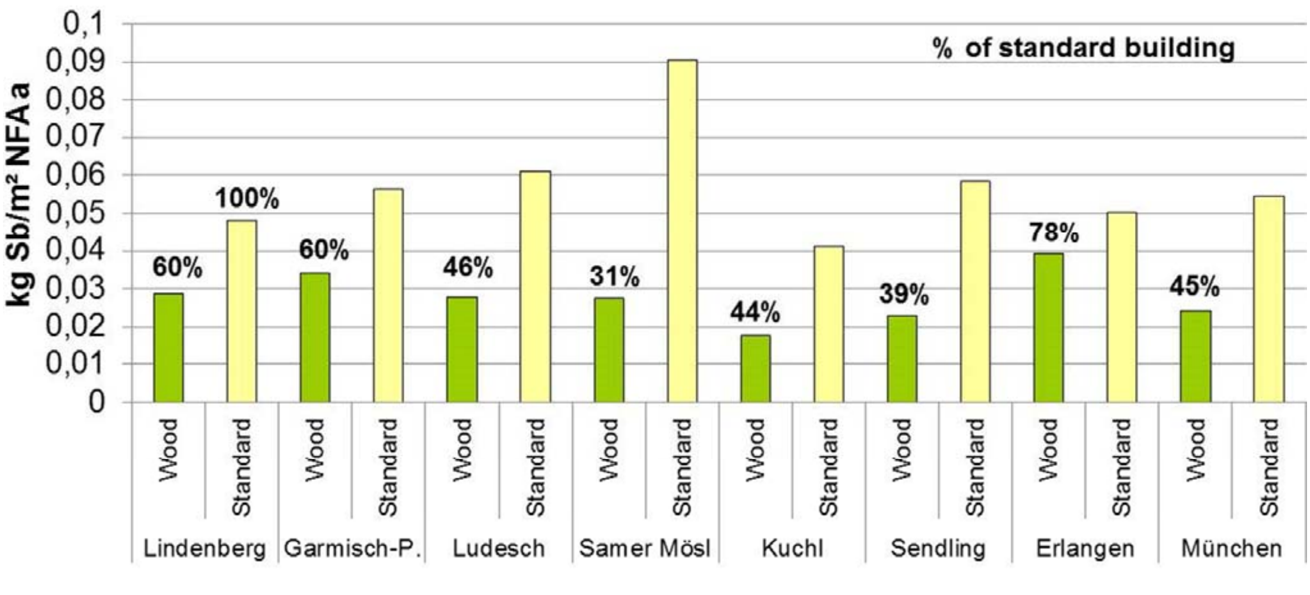


Fig. 5 Global Warming Potential (GWP), only building, 50 years, kg CO_2 eq./m² NFA a

3.2.3 Abiotic depletion potential

The consumption of abiotic resources shows nearly the same difference between the two building concepts. The buildings with a high rate of renewable raw materials have a 22 - 69 % lower consumption compared with the "standard version" buildings (Fig. 6).



3.3 Carbon storage and substitution

Two aspects of renewable raw materials used in the buildings sector have to be regarded: The building as carbon (C) storage and the possible substitution of non-renewable materials.

3.3.1 Carbon storage

The capacity of C-storage during the use phase of the building is important because the carbon stays for a period of 50 or 100 years in the building. This will unburden the climate of CO_2-emissions. A condition for the calculation is the origin of the wood from sustainable managed forests, like it is practised in Middle Europe. Keeping the level of C-storage of these forests is a must for the positive contribution input for climate protection [5]. Due to this the certification systems in Germany (DGNB, BNB, NaWoh) challenge to proof that the built-in products from renewable raw materials is labelled by FSC (Forest Stewardship Council) or PEFC (Program for the endorsement of forest certification schemes). The C-storage for the “standard version” reaches only 1 to 6 kilogramm per m² GFA. The buildings with a high quotient of renewable materials reach 44 - 87 kilogramm C per m² GFA (Fig. 7). The calculation is based on a catalogue published in 2014 by the IPCC, on how much carbon is stored in different wood products. Roughly the figures show a content of 250 kg carbon in one m³ of wood (density atro 450 kg). The carbon storage value can be tranformed in CO_2 using the factor 44/12.

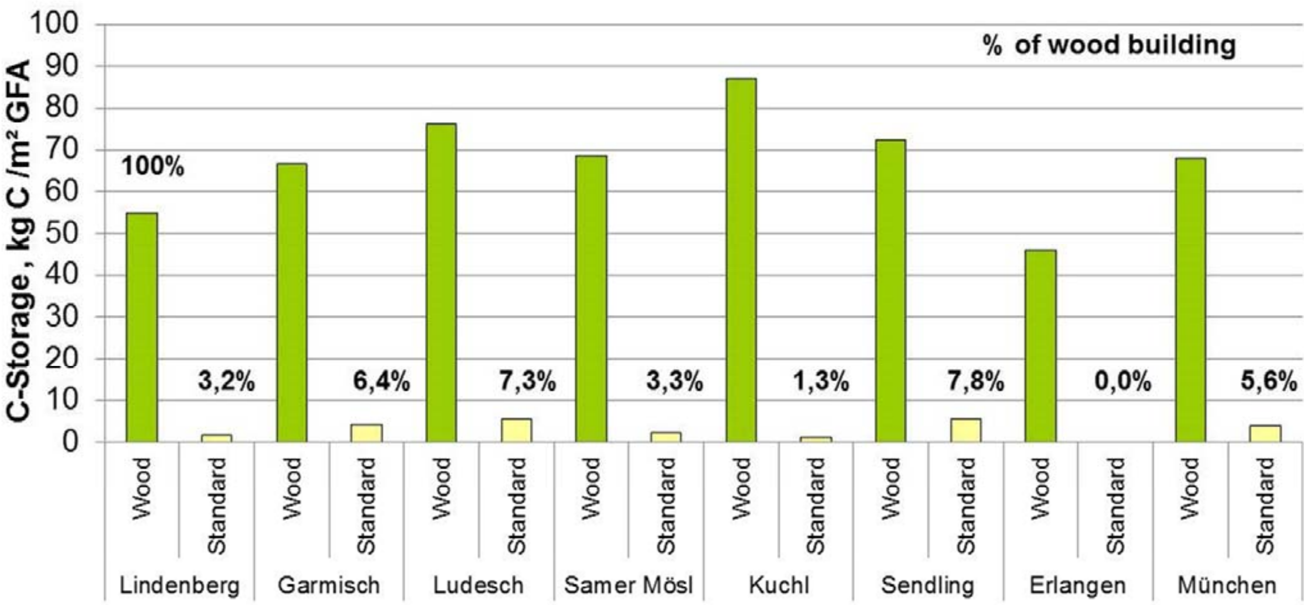


Fig. 7 Carbon storage, kg C/m² GFA

3.3.2 Substitution of non-renewable materials

Building products derived from renewable raw materials can substitute materials of non-renewable resources. The condition to evaluate the quantity of the savings potential is a comparison of the same functional unit. In this research the functional unit of the comparison is the building. As above mentioned the exact modelling ensures the same size, quantities, energy demand, the fire resistance, the noise reduction and technical equipment. The value varies depending from the environmental indicator chosen. For the GWP the use of wooden construction products avoids between 0.9 to 1.9 t per m³ wood built-in (Fig.8).

This calculation result is similar to the values documented in other research studies by Sathre and O’Connor [6] and by the International Institute for Environment and Development [7].

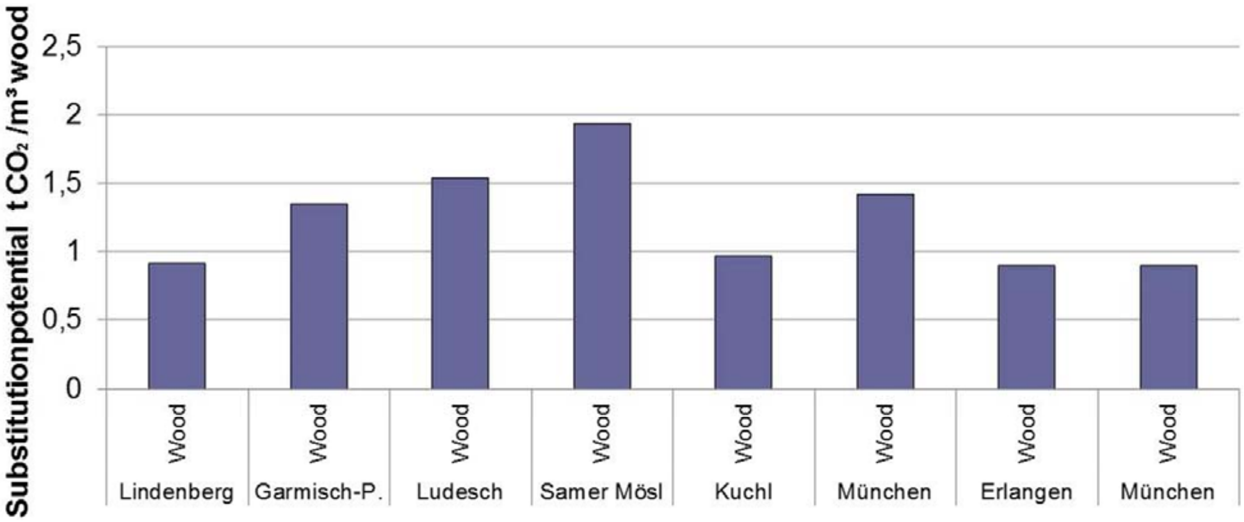


Fig. 8 Substitution of non renewable materials, t CO_2/ m³ wood built-in

4. Conclusion

In comparing conventional constructed buildings - which contain numerous construction products derived from finite resources - with buildings (with a high proportion of building products derived from renewable raw materials) the LCA-results show, that significant ecosystem load reduction potentials are offered by the latter construction method. A large proportion of current conventional construction assignments (from residential to commercial) could be accomplished by using components which are made from renewable raw materials. In the objects presented here, products (manufactured by sustainable raw materials) were used for the load-bearing construction of the outer and inner walls, ceilings, supports and roofs, façade cladding, sun protection, insulation and interior fittings. The aim of the research project in regenerative potential was used to better establish the special properties of renewable raw material product groups by compiling a comparative eco-balance.

Due to the new rules for environmental product declarations based on EN 15804, the database for ecobalances in Germany has been changed in 2015. To clarify the consequences in calculation and results of a new research project is on the way: The THG-Holzbau project („Greenhouse gas balances for timber buildings – Implementation of new requirements for life-cycle-assessments and calculation of empiric substitution factors - GHG-timber buildings/Waldklimafonds). In this research project empiric substitution factors for timber buildings will be identified based on the new standards in LCA calculations. These data get transfered into the database of the software LEGEP for sustainability assessment.

Beside positive substitution potential of wooden products, the carbon storage for timber buildings gets quantified for Germany to show possible consideration in the Kyoto-protocol. Based on actual market share of timber buildings the project will show the impact of changes in market share for use of wood until 2020 and their impact on greenhouse gas emissions. To overcome obstacles in timber constructions, which oppose rising share of wood, practical solutions are developed.

5. Acknowledgements

The research project “Innovative Bilanzierungsmethode zum Baustoff Holz als Beitrag zur Ausstellung Bauen mit Holz – Wege in die Zukunft“ [8-11] was fundend by the German Federal Environmental Foundation (DBU- Deutsche Bundesstiftung Umwelt). The exhibition “Building with wood – path into the future” was opened 2011 in the Museum of modern Art, department collection of architecture in Munich and was also presented in Vienna.

The choice of the objects was done by Prof. Hermann Kaufmann. The architecture models for the exhibition were produced by students at the Technical University of Munich.

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Certification of Sustainability: Results from Practice

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Summary

In the last years the Assessemnt System for Sustainable Building (BNB) was established as one of the most important instruments for the implementation of higher quality requirements for federal buildings in Germany. Now the first results of complete certification processes according to BNB are available. As one of the first federal buildings the new Ministry of Education and Research in Berlin and the new Federal Environment Agency in Berlin were certified with the BNB Gold Certificate. These outstanding pilot projects are now the best federal buildings according to proven sustainability requirements and the experiences can be used for new recommendations or future requirements.

Keywords: assessment system for sustainable building (BNB); results of certification; best practice; new sustainability requirements of German government; federal project with highest sustainability standard

1. Introduction

Building in Germany is being geared towards sustainability. The German criteria checklist for the comprehensive assessment of sustainability aspects of buildings was developed by the Federal Building Ministry and the German Sustainabilty Council DGNB and is now used by the public sector and in a similar way by the private development sector.

The Assessment System for Sustainable Building (BNB) focuses on the entire life cycle of the built environment, covering all aspects from planning and construction to building operation with a view to optimizing overall quality.

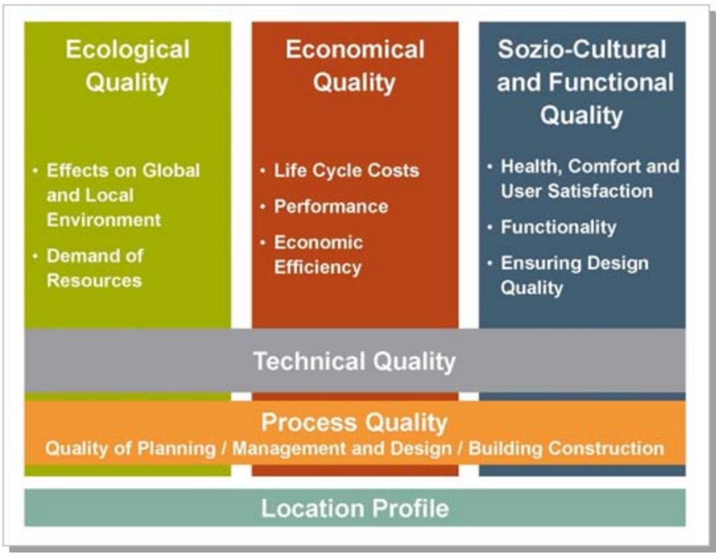
As part of the German government, its sustainability strategy is assuming an exemplary role in implementing sustainability objectives in construction. Specific requirements for federal building projects are set out in the Sustainable Building Guidelines and the associated assessment system BNB. The overall requirement is to attain the “Silver Standard” according to BNB for those federal buildings for which a BNB variant is available. As a result the BNB was established as one of the most important instruments for the implementation of higher quality requirements for federal buildings.

Since January 2015 the first results of complete certification processes are available. As one of the first federal buildings the new Ministry of Education and Research in Berlin and the new Federal Environment Agency in Berlin were certified with the BNB Gold Certificate.

2. Implementing Sustainable Requirements for Federal Buildings

2.1 Principles of Sustainable Building

In general, the classical understanding of sustainability is based on three dimensions: ecology, economy and socioculture, which are to be considered over a long period of time. The goal is to observe and to evaluate the entire useful life of a building – colloquial referred to as the life time of a building. For the actual observations of the life cycle, the first 50 years of a building are worked into the calculations.



Nachhaltiges Bauen

Fig. 1 Qualities of Sustainable Building
Fig. 2 Logo of BNB in Gold © BMUB

The main goal sought in the ecological dimension is primarily the protection of resources by optimally using construction materials and products, minimising use of space and of media (e.g. heat, electricity and water).

All requisite energy and material flows from the gain through the refinement and transport to the installation or disassembly alongside the global and local effects on the environment made by the energy use of the construction materials or the buildings are considered. Generally, this reduces environmental pollution at a local and global level. Different methods of analysis, e.g. risk analysis, analysis of the material flow, the material analysis and the ecological balance, are to be applied to objectively assess the environmental compatibility of construction products and of the whole building concept.

The costs which go above and beyond the mere costs of purchase and assembly – especially the life cycle costs are considered in the economical dimensions of sustainability. This places the focus on life cycle costs relevant to the building, the economic viability and the value stability. As practice has shown, the life cycle costs can by far exceed the costs of construction. By analysing the life cycle costs, considerable opportunities for saving money during planning can be identified.

As Life-Cycle-Costs (LCC), the costs of construction, the construction use costs and the demolition costs are additionally considered.

In addition to the question of functionality, the question of aesthetic design, the health aspects and comfort are relevant points in considering the social and cultural dimensions of sustainability. Winter and summer heat insulation contribute to comfort just as much as the noise protection or a deliberately chosen type of construction material (e.g. the use of emission free products). Construction designs, choice of material, building construction and technology are to be interpreted to that effect and to be optimised, if needed. At the same time the construction design is to be made flexible enough that it can be easily adapted to the changing parameters e.g. change of use/user.

Alongside the ecological, economical and sociocultural aspects, the functional and technical properties (technical quality), the planning and implementation (process quality) and the local characteristics are decisive for the description and value of a building. This has extended the three columns of sustainability to five quantifiable qualities of sustainability – informatively supplemented by the local characteristics. The various aspects of sustainability interact directly with each other, so that the goal becomes a holistic and simultaneous assessment of every aspect.

2.2 How to use the “BNB”

The planning-based Assessment System for Sustainable Building (BNB) is distinguished for its comprehensive consideration of the entire life cycle of buildings.

The assessment of building qualities is accomplished in accordance with transparent rules and objective, essentially quantitative methods.

No individual measures are evaluated in the results-oriented system, but rather their documentable effect on the overall concept of the building. Its application takes place throughout the planning stages, which means that it contributes not only to the optimization of the building but also and at the same time to quality assurance.

The BNB is organized into three different levels. The actual definition of the qualities takes place on the criteria level. These are described in detail in 46 criteria profiles on the basis of a total of around 150 indicators. The criteria profiles are grouped thematically in 11 criteria groups and 6 main criteria groups, thus making it possible to identify special qualities on each level.

On the basis of the degree of fulfilment, a score is assigned to the quality levels – Gold, Silver or Bronze. The results are presented in greater detail on a certificate with the logo of t BNB, representing the respective quality level. Additional information regarding the building is contained therein.

The modular structure of the system enables a differentiated presentation of the results; particular attention can thus be drawn to exceptional qualities in one or more subordinate areas of the assessed building. The BNB and additional planning tools are published via the Sustainable Building Information Portal of the Federal Building Ministry (www.nachhaltigesbauen.de). Some selected contents are available in English.

3. Certification of the Federal Ministry of Education and Research in Berlin

3.1 General Information on the Project

The new Federal Ministry of Education and Research in Berlin is the first federal civil building project that was realised by Public Private Partnership (PPP) and also the first building of that kind and size that received a certificate of BNB in gold. The project distinguishes itself by very high qualities and degrees of fulfilment in all main criteria groups of the assessment system BNB (81% - 99%).

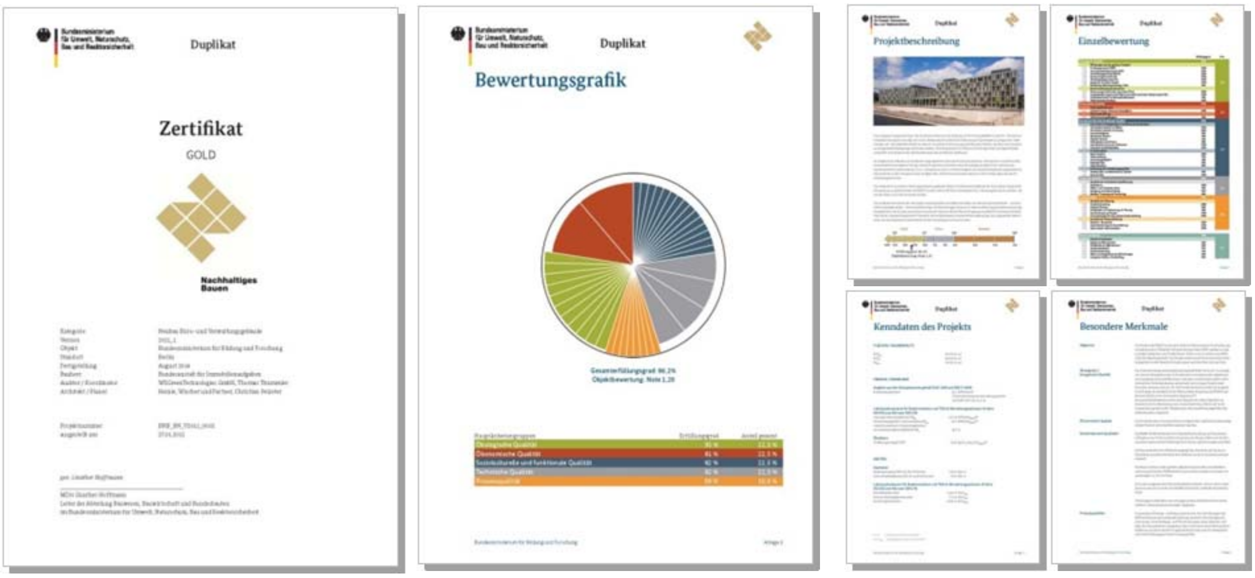


Fig. 3 BNB Gold Certificate for BMBF

This outstanding pilot project is now the best federal building according to proven sustainability requirements.

The six-storey building of the Federal Ministry of Education and Research (BMBF) was designed for 1000 office workplaces and is integrated in the existing development at the Berlin “Spreebogen” vis-a-vis the government district as a recognizable city block.

Fig. 4 Federal Ministry of Education and Research in Berlin (BMBF)
Fig. 5 Interior Courtyard

Table 1: Characteristics of BMBF

Users	Federal Ministry of Education and Research and others
Owner	Institute for Federal Real Estate (BImA)
Building Category	Administration Building
Type of Project	Public Private Partnership (PPP)
Total Building Costs	115 million Euro
Architect	C. Pelzeter; Heinle, Wischer und Partner, Berlin
Building Company and Contractor	BAM Deutschland AG
Completion	August 2014
Gross Floor Area	58.000 m²
Workplaces	1.000
BNB Certificate	Gold (86.2%)

The building is composed of two U-shaped office wings which are connected by a central block. The greened and noise-protected interior courtyards are opened to the railway line and thus enable a visual connection to the northern urban space.

On the ground floor there are the entrance area with a visitors center, a canteen, a library, childcare facilities, five greened interior courtyards and the two-storied foyer that leads to the conference center on the first floor.

The offices on the upper floors are mainly designed as single-user workplaces and are supplemented by spacious open communication areas in the central corridors.

The building is structured in several utilization units. Beside the 350 office workplaces for the employees working in Berlin, other 650 office workplaces, which are rented to third parties, were realized in a second utilization unit.

The building features an excellent overall quality that is recognizable by the gold certificate with a degree of fulfilment of 86.2 % and it features a number of over-average – and in parts outstanding – specific qualities according to sustainable building as shown subsequently.

3.2 Specific Qualities according to Sustainability

3.2.1 Ecological and Energetical Quality

The energy concept for BMBF combines measures of optimizing the building physics according to the construction and technical systems which are in some places conventional and in other places very innovative.

As a result the energy demand of only 36.1 kWh/(m²a) deceeds the strict requirements in Germany for this project by 71.6 %.

Special and innovative features of the building for reducing the energy demand are for example:

- optimized heat insulation (heat transfer coefficient walls: 0.19 W/(m² K); heat transfer coefficient windows 0.84 W/(m² K))

- photovoltaic modules on the flat roof and integrated in the façade that produce about 100000 kWh electric energy per year
- thermal activated ceilings instead of radiators in the offices
- ventilation system with heat recovery in every office, in conference rooms sensitive to CO_2 concentration
- LED lighting sensitive to movement and daylight in all offices
- external jalousie with light-diffusing slads in upper third and internal sun-blind with translucency in upper third for maximizing daylight even in a closed state
- combined heat and power (CHP) with block-type thermal power station (BTTP) and gas-powered fuel cell for generating electricity, heat and cooling instead of district heat (this system minimizes the primary energy demand and the CO_2 emission)
- the different system components are cross-linked with the building management system (BMS) by an intelligent interconnection (smart grid)



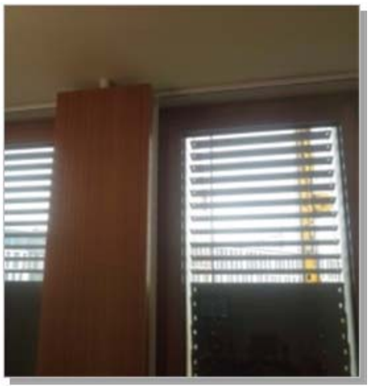


Fig. 6 PV Modules in the Façade
Fig. 7 LED Lighting; Sun Shutter with partly Translucency
Fig. 8 Jalousie with light-diffusing Slads

Table 2. Characteristics of Fuel Cell System in BMBF

Type	Molten Carbonate Fuel Cell, MCFC
Producer	Fuel Cell Energy Solutions GmbH
Electrolyte	carbonated
Operating Temperature	600–650 °C
Fuel Gas	natural gas
Output Power	250 kW electric, 160 kW thermic
Efficiency	47 % electric, 79 % total (acc. to lower heating value)
Savings Compared to Seperated Generation	about 30 %

3.2.2 Economical Quality

The project could be realized in a high economic efficiency with a high energy quality and a high level of comfort for the user.

In order to ensure the flexibility and adaptability of the building for possible changing user demands in the future, the building enables different types of efficient office structures.

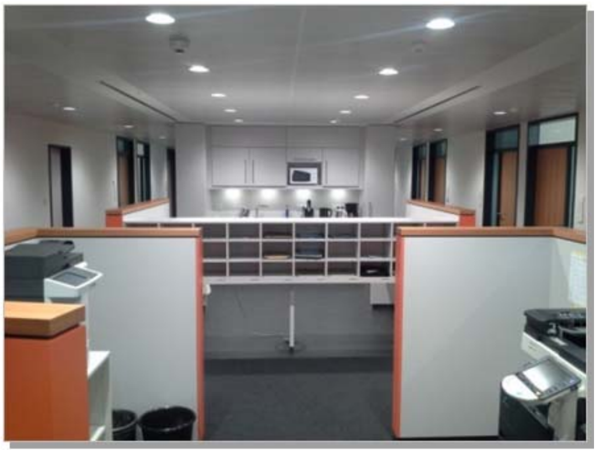


Fig. 9 Communication Area
Fig. 10 Office Facilities, Mailboxes and Tea Kitchen in open Areas

3.2.3 Socio-cultural and Functional Quality

The requirements according to the user demand for a high level of comfort are met by numerous aspects, as for example:

- According to indoor air quality and avoidance of harmful substances the highest quality levels of BNB were met by choosing low-emission building products.
- The accessibility of the foyer and of the office areas is over and above the normal standard (building, interior courtyards and floors are accessible without steps; well-spaced corridors and office rooms for wheelchair users; tactile guidance strips; speech modules in elevators; information in Braille or raised letters; barrier-free toilets on every floor).
- A competition for art in architecture was realized with more than 300 submitted designs of which 4 were chosen: a sandblasted lettering „warum weiss ich nicht einfach alles" ("why do I not know just everything") at indoor glazing (artist: E. Prautzsch); a virtual sculpture of air, light and water vapour with a connotation to a rainbow at the banister in the foyer; a mirror glas with 2000 LED lights at the interior wall of the conference center illustrating fictive constellations; a slate of 30m² with a machine that writes computer-operated sketches, graphs and patent drawings with chalk.
- 282 bicycle stands are available for the employees.
- A high level of noise protection was realized.

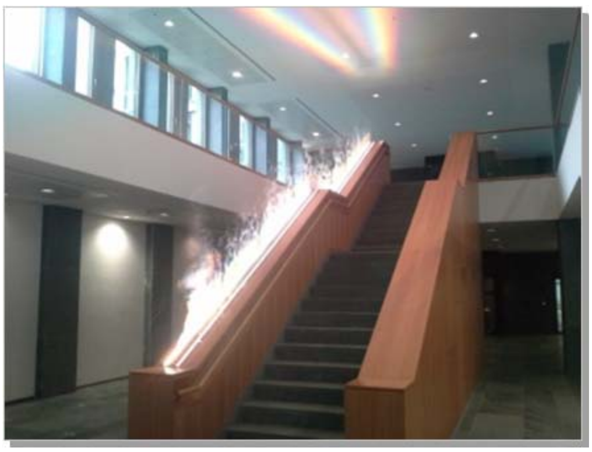
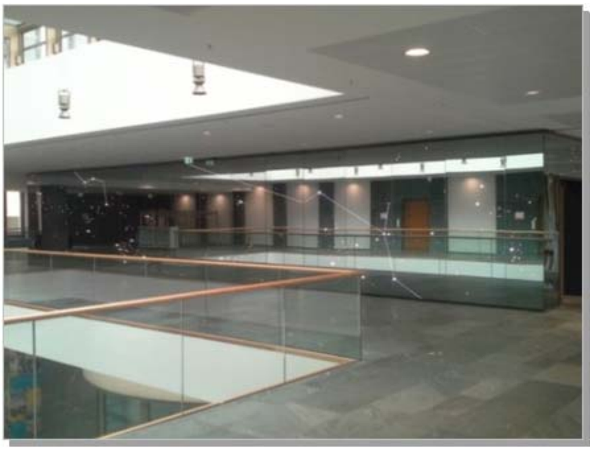


Fig. 11 Tactile Guidance Strips
Fig. 12 Virtual Sculpture (artists B. Burchhardt, A. Lippke, M. Stammen)



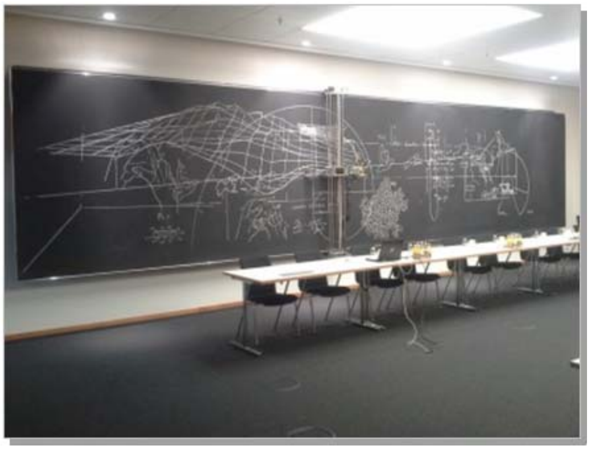


Fig. 13 Mirror Glas with 2000 LED (artists A. Anklam, T. Henninger)
Fig. 14 Slate with Writing Machine (artists A. Anklam, T. Henninger)

3.2.4 Process Quality

An interdisciplinary planning team enshured that the requirements of sustainable building were adhered to using an integral planning and a holistic approach during the whole planning and building process. The procurement and the supply of materials were controlled with an extraordinary effort and the extent and quality of the building and material documentation is exemplary. The degree of fulfilment of the requirements of BNB according to process quality is 99%.

4. Other Examples

Beside the BMBF numerous other current federal building projects consider the requirements of the BNB, like for example:

The new office building for 30 employees of the Federal Environment Agency in Berlin is designed as the first federal “zero energy building” and received the certificate of BNB in gold in 2015 (more information: www.umweltbundesamt.de/).

The renovation and reconstruction of the listed Federal Constitutional Court in Karlsruhe received the first certificate in silver according to BNB for complete refurbishment (more information: www.bnb-nachhaltigesbauen.de/).

The aim for the new extension building for 100 employees of the Federal Environment Agency in Dessau is a “zero energy building” and a certificate of BNB in gold (more information: www.umweltbundesamt.de/).

The aim for the new exhibition and event building of the Federal Ministry of Education and Research in Berlin called “House of the Future“ is a quality of sustainability analogue to “BNB Gold” (more information: www.hausderzukunft-deutschland.de/).

5. Conclusion

All these projects are a part of the sustainability strategy of the federal government and they demonstrate that higher qualities according to the holistic approach of sustainability can be implemented in daily praxis. The experiences can be used for new recommendations or future requirements for sustainability projects in the public sector.

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Characterization of Fly Ash/Metakaolin-based Geopolymer Lightweight Concrete Reinforced Wood Particles

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Summary

This paper reported on the properties of fly ash/metakaolin-based geopolymer lightweight foamed concrete with inclusion of wood particles. Class F fly ash and metakaolin was mixed with an alkaline activator solution (a mixture of sodium silicate; Na_2SiO_3 and sodium hydroxide; NaOH), and hydrogen peroxide; H_2O_2 was added to the geopolymeric mixture to produce lightweight foamed concrete. The NaOH solution was prepared by dilute NaOH pellets with distilled water. The ratio of fly ash/metakaolin and alkaline activator used was 2.5:1.0 with addition of 0%, 10%, 20% and 30% of wood particles by volume of the total mix. The reactive were mixed to produce a homogenous mixture sized 50mm and cured at two different curing temperatures (80^{o}C for 24 hours and room temperature for seven days). All the experiments were set up in accordance with International standard methods of testing. In reference to the analysis and discussion, the integration of fly ash/metakaolin and wood particles enhanced the properties of the lightweight foamed concrete. The results showed that the samples which were cured at 80^{o}C produced the maximum compressive strength, (5.71 MPa, 10.2 MPa, 7.62 MPa and 6.3 MPa) for 0%, 10%, 20% and 30% of wood particles respectively. The oven-dry density of samples cured at 80^{o}C was greater than room temperature curing. Heat curing which caused the geopolymerization rate to increase, producing a denser matrix. The water absorption and porosity were reduced in parallel of increasing percentage of wood particles for both curing conditions samples. The results also indicate that there is a potential to use the geopolymer as a binder for novel lightweight wood concrete for non-loadbearing applications.

Keywords: geopolymer; lightweight, wood particles, metakaolin; fly ash

1. Introduction

Lightweight foamed concrete (LFC) becomes an innovative product for the construction industry nowadays. Different than conventional concrete, density of lightweight concrete usually ranges from 300 to 1800 kg/m^3 whereas density of normal concrete is approximately 2400 kg/m^3 [1]. It has a number of attractive advantages such as good thermal and acoustic insulation [2], better fire protection and easy to fabricated [3]. Although its mechanical properties are low compare to normal concrete, LFC may be used as partition or light load bearing walls in low-rise residential construction and as filler in civil engineering works [2]. LFC is lighter than normal weight concrete due to consists of entrapped bubbles acting as aggregate in its cement mortar. LFC can be prepared either by using suitable foaming agent or by injecting air or by omitting the finer sizes of the aggregate or by replacing them with hollow, cellular or porous aggregate [4]. Using lightweight aggregate is one of the most common ways for making LFC.

There have been numerous studies focusing on various types of additions and replacement of aggregates to enhance LFC durability and mechanical properties. By far, both synthetic and natural resources fibers have been in practice since the early civilization [5]. Besides its economic advantages, the main reason for their use is that they encounter certain problems regarding its mechanical and durability properties of concrete.

The types of natural fibers used in Portland cement concrete include agricultural residues, lignocellulose material and wood particles including rubber wood, pines, acacia and cypress [6]. In comparison with synthetic fibers, natural fibers are believed to be more environmental friendly, low density, recyclable and biodegradable. Although the strength properties of these natural fibers are slightly lower than the concrete mix [6], its offer signification reduction in the cost and also associated benefits during processing.

Recently, the potential for replacing Ordinary Portland Cement (OPC) and rapid-hardening Portland cement which were used in common foamed concrete has been explored extensively by researchers as its production creates environmental pollution due to release of CO_2. ‘Geopolymer’, a term to describe inorganic polymers based aluminosilicate which rich in silicon (Si) and aluminum (Al), produced by reacting with highly alkaline solutions [7] was discovered to replace cement based binder. The manufacturings of foamed materials using geopolymer have attained a lot of interest. The pore system in geopolymer based material is conventionally classified as gel pores, capillary pores, macro-pores due to deliberately entrained air, and macro-pores due to inadequate compaction [8]. Many natural mineral or by-product materials rich with SI-Al could become the sources for making geopolymers, such as fly ash, metakaolin, furnace slag, silica fume, mine tailings, pozzolan, kaolin, building residues and some natural minerals.

In this research, the main goal is to develop lightweight foamed inorganic construction material from fly ash, metakaolin and wood particles aggregates. Potential applications might include lightweight wood composite for non-load bearing walls. The evaluation criteria include compressive strength, oven-dry density water absorption and porosity. Preliminary findings are reported in this paper.

2. Methodology

Fly ash, metakaolin, sodium silicate (Na_2SiO_3), sodium hydroxide (NaOH), wood particles of mixed softwood and hydrogen peroxide (H_2O_2) which act as foaming agent were used to produce the lightweight geopolymer composite concrete. The fly ash used was Class F, provided by GK Kiel GmbH power plant, Germany, and its chemical composition are listed in Table 1. Metakaolin (brand name Argical M1000) is obtained from AGS Mineraux, Clérac, France. The Na_2SiO_3 (brand name Betol 52 DS) composition was 30.2% SiO_2, 14.7% Na_2O and 55.1% H_2O with a SiO_2/Na_2O molar weight ratio of 2.0 with a density of 1.54g/cm^3 at 20^{o}C according to the specification of the producer (Woellner GmbH & Co. KG, Ludwigshafen am Rhein, Germany). Laboratory grade NaOH beads are from Fisher Scientific. The wood particles, obtained from a local particle board mill, were sieved to the average <1.5-3.0mm. The moisture content was 3.52%.

Table 1: Chemical composition (% mass) of fly ash used in this study (from GK Kiel power plant)

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	SO_3	Carbon	Other	Total
56.8	23.8	6.79	2.9	1.28	0.43	1.99	0.67	0.43	3.5	1.41	100

In this study, four standard mix compositions; A, B, C and D are shown in Table 2 were used. These standard mix compositions are determined from the pre-trial mix. The ratio of Na_2SiO_3/NaOH used in this research was fixed to 2.5. The solution is prepared by first dissolving NaOH in water and mixing with Na_2SiO_3. This is an exothermic process and the temperature rises rapidly to about 90°C. The solution is allowed to cool down at room temperature before mixing to avoid any circumstances during geopolymerisation. The mix proportions of fly ash and metakaolin, as well as the alkaline solution and the constant percentages of H_2O_2 as shown in Table 2 were mixed for 10-15 minutes until homogeneity was achieved. 0%, 10%, 20% and 30% of wood particles by volume of total mix was added. The resulting sludge was poured into the 50 x 50 x 50mm³ molds. The samples were cured at two different conditions: (a) at 80°C for 24 hours; (b) at room temperature (~22°C) for 7 days.

Table 2: Mix composition of lightweight foamed geopolymer composite at lab scale used in this study

No	% Aluminosilicate		% Wood	% H_2O_2	Alum:AL	Na_2SiO_3:NaOH
A	70 fly ash	30 metakaolin	0	5	2.0:1.33	2.5:1.0
B	70 fly ash	30 metakaolin	10	5	2.0:1.33	2.5:1.0
C	70 fly ash	30 metakaolin	20	5	2.0:1.33	2.5:1.0
D	70 fly ash	30 metakaolin	30	5	2.0:1.33	2.5:1.0

The compressive test of the samples was performed on a Mannheimer Maschinenfabrik Mohr & Federhaff AG testing machine using a speed rate of <10mm/min using 50 mm cube samples. Seven samples per batch are tested, with the average strength values reported in this paper.

Water Absorption and porosity of each cube sample are measured according to ASTM C642. Three specimens from each batch were immersing in water at room temperature (22°C) for 24 hour. The absorption, porosity and oven-dry density are calculated by the equation below;

$$\text{Water Absorption (\%)} = [(W_s - W_d) / W_d] \times 100 \quad (1)$$

$$\text{Porosity (\%)} = [(W_w - W_d) / (W_w - W_s)] \times 100 \quad (2)$$

$$\text{Density (kg/m}^3\text{)} = [W_d / (W_s - W_w)] \times 1000 \quad (3)$$

Where;

W_s = saturated weight (kg)
W_d = oven-dry weight (kg)
W_w = immersed weight (kg)

3. Results

The compressive strength, water absorption, porosity and oven-dry density of all the samples cured under two different conditions are listed in Table 3. All the results mentioned in Table 3 were the mean from seven tested samples for compressive strength and three samples for water absorption, porosity and oven-dry density.

Table 3: Compressive strength, oven-dry density, water absorption and porosity of composition A, B, C, D and E under two different curing conditions

	Compressive Strength (MPa)		Oven dry Density (Kg/m^3)		Water Absorption (%)		Porosity (%)	
Conditions	80^oC	RT	80^oC	RT	80^oC	RT	80^oC	RT
A	5.71	5.20	524	456	17.5	11.11	73.68	71.43
B	10.2	6.35	887	750	8.57	11.38	52.17	45.16
C	7.62	5.85	725	665	6.67	7.14	22.22	26.67
D	6.30	5.58	535	514	6.61	5.17	23.53	20.69

3.1 Compressive Strength

The results of compressive strength for 0%, 10%, 20% and 30% of wood particle reinforced lightweight foamed geopolymer concrete is shown in Figure 1.

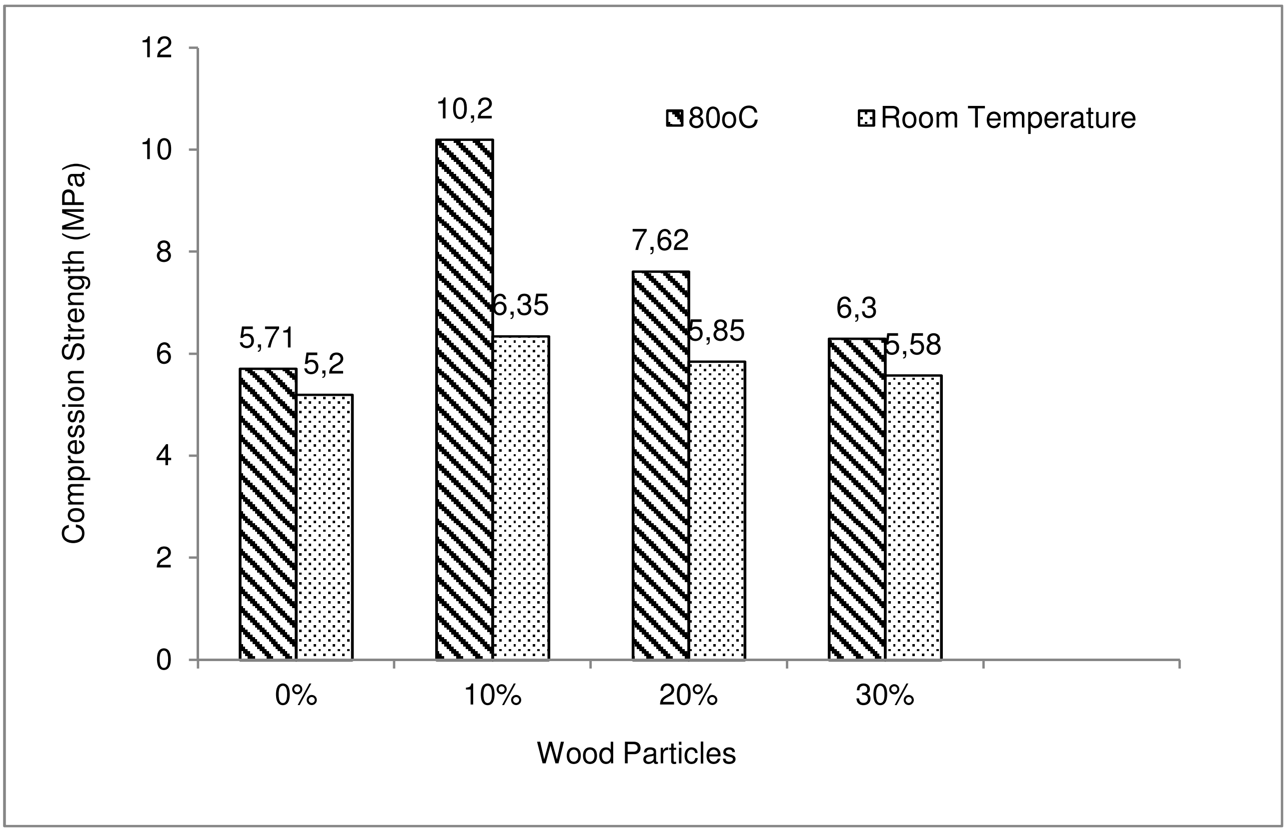

Fig. 1 Compressive strengths for two different curing condition of lightweight foamed geopolymer concrete with 70% fly ash and 30% metakaolin with addition of 0%, 10%, 20% and 30% of wood particles

The figure shows that specimens cured at 80^{O}C experienced greater strength compared to specimens cured at room temperature. Specimens without wood particle inclusions recorded a lower strength; however specimens at 10%, 20% and 30% of test showed a positive enhancement. The highest strength increment can be seen in the mixes with 10% wood particles followed by 20% and 30%. While for specimens cured at room temperature, the compressive strength was lower compared to the 80^{o}C samples. There has not been much different between 0%, 10%, 20% and 30% of wood particles in contribution to compressive strength for specimens cured at room temperature.

3.2 Oven-dry Density

By referring to Figure 2, there has not been much difference between 80^{O}C and room temperature curing in oven-dry density value. As shown in Figure 2, the value of oven-dry density decrease due to the increment of fiber content percentage. For sample cured at 80^{O}C, the highest density is at 10% of wood particle content which is 887kg/m^3 and the lowest is 524kg/m^3, while for room temperature, the highest value of oven-dry density is 750kg/m^3 and the lowest is 456kg/m^3. This result showed the reduction of density at an increasing level of the inclusion of wood particles.

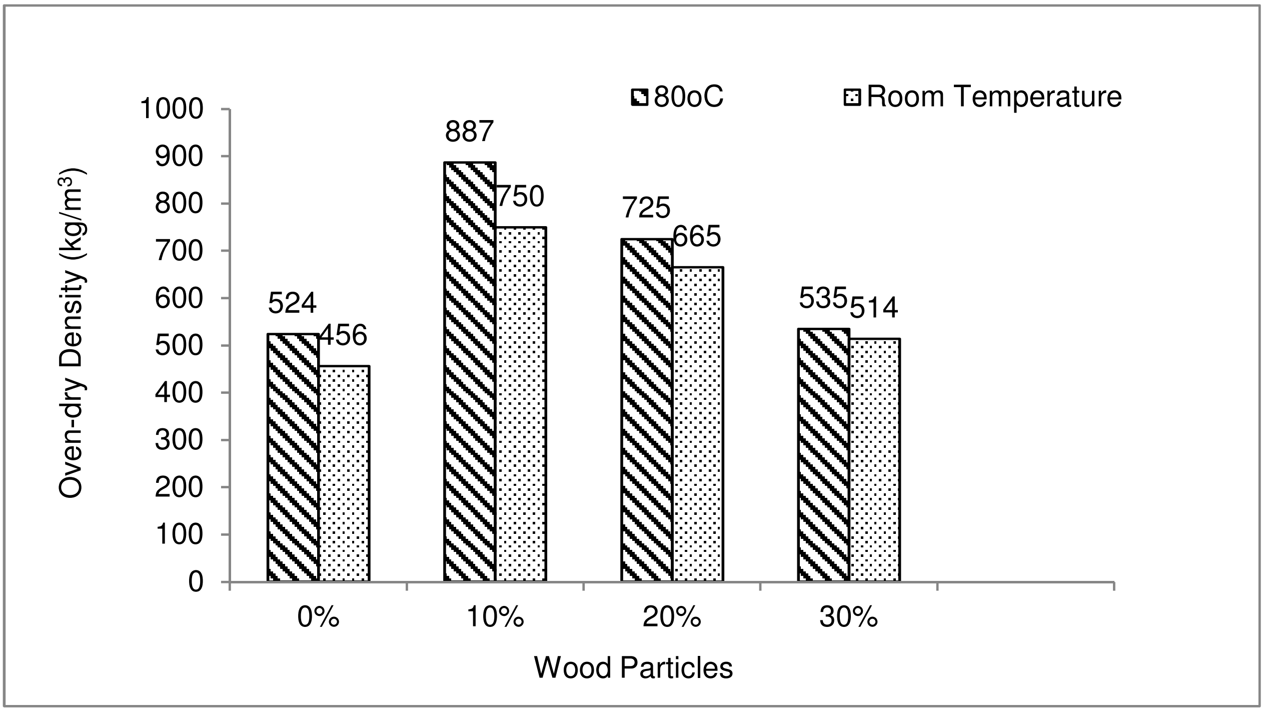

Fig. 2 Oven-dry density for two different curing conditions of lightweight foamed geopolymer concrete with 70% fly ash and 30% metakaolin with addition of 0%, 10%, 20% and 30% of wood particles.

3.3 Water Absorption

The percentage rate of water absorption for 0%, 10%, 20% and 30% of wood particles specimens is presented in Figure 3. It can be drawn that the lowest result in the rate of water absorption illustrated by specimens at 30% of wood particles inclusions for both curing conditions. This is followed by specimens at 20%, 10% and the highest, 0%. The pattern of adding wood particles mixes shows a positive result by which it decreases the percentage rate of water absorption.

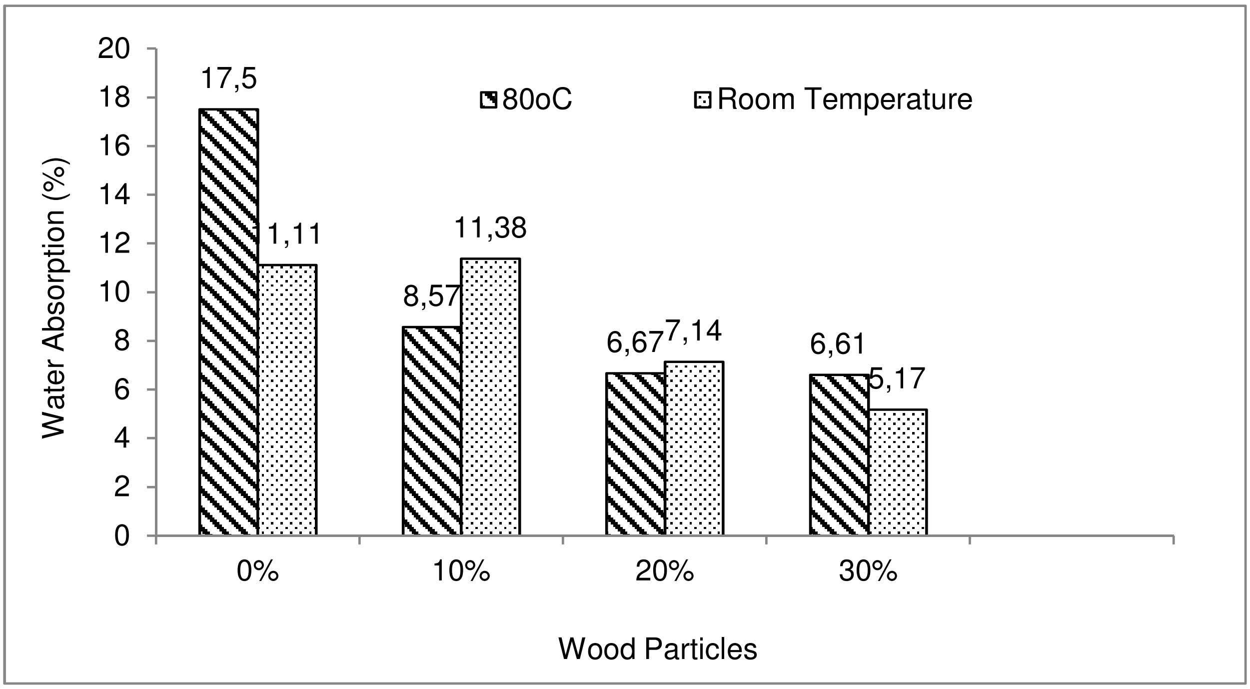

Fig. 3 Water Absorption for two different curing conditions of lightweight foamed geopolymer concrete with 70% fly ash and 30% metakaolin with addition of 0%, 10%, 20% and 30% of wood particles.

3.4 Porosity

The porosity of the foamed geopolymer concrete is the sum of the entrained air voids and the voids within the paste. As seen in Figure 4, the percentage rate of porosity is decreased with increasing percentage value of wood particles for both curing conditions. The 0% wood particles specimen possesses the highest value of porosity while 30% of wood particles experienced the lowest.

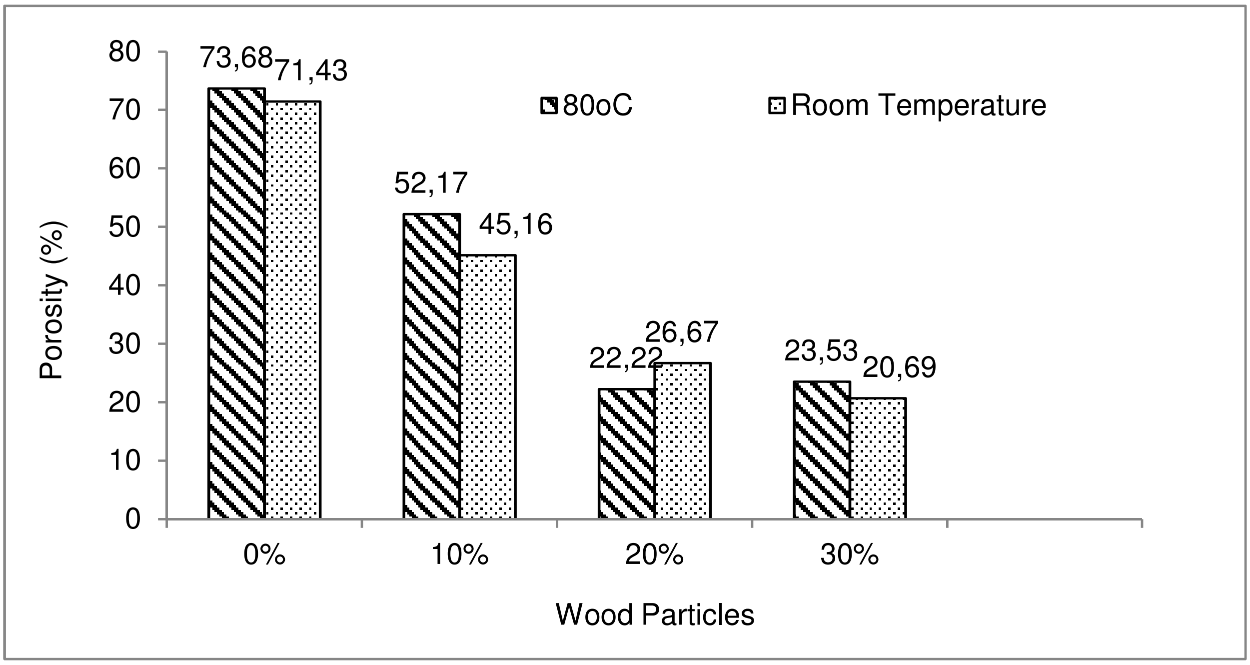

Fig. 4 Porosity for two different curing conditions of lightweight foamed geopolymer concrete with 70% fly ash and 30% metakaolin with addition of 0%, 10%, 20% and 30% of wood particles

4. Discussion

From the finding, the maximum compressive strength was observed in the samples that had been cured in the oven, 80°C. This proved that heat treatment is required to expedite the rate of geo-polymerisation. The strength of the samples made with 10% wood particles is higher than those with 20% and 30% wood particles. The addition of wood particle developed higher compressive strength which may be due to the fact that the compability of the wood particles with geopolymer was improved considerably. However, when the amount of wood particles increased, the strength will be decreased respectively. The inclusion of fibre is known to decrease the average compressive strength of concrete [8]. This is due to the problem of increasing water demand to reach good workability thus lessening the concrete average compressive strength. This theory can be applied to the hydrophilic type of fibre [8].
It is expected that the 20% and 30% wood particle inclusions specimens showed higher water absorption. However, the water absorptions of both samples are reducing while the amount of water absorption for 10% wood particle samples was increasing. The possible reason could be attributed to low oven-dry density of the samples, which cause more void space in the composite. This can be proving from the percentage of porosity. Another possible reason is that the lower bonding strength between the wood particle and geopolymer led to tendency for more spring back after 24-h of water immersion.

5. Conclusion

Based on the obtain data in this study, incorporation of the wood particles and mixes of fly ash with metakaolin had comparable effects in the compressive strength, oven-dry density, water absorption and porosity. Lightweight concrete mixes with 10%wood particles with 70% fly ash and 30% metakaolin obtained higher compressive strength and acceptable value of water absorption rate, oven-dry density and porosity. These materials have relatively low density compared with normal concrete. Thus, it was suitable for either an insulating material, or a non-load bearing building material. However, extra research needs to be done in terms of enhancing the bonding between wood and geopolymer.

6. Acknowledgements

The authors would like to extend their gratitude to University of Hamburg and Thünen Institute of Wood Research for the research opportunity. The authors also acknowledge the Ministry of Higher Education, Malaysia and Universiti Teknologi MARA, Malaysia for scholarship and granting study leave for Siti Noorbaini Sarmin.

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Climatic Zones in Poland and the Demand for Heating in a Typical Residential Building

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Summary

Demand for heating in buildings depends to a large extent on climatic conditions, specific for its location. In the territory of Poland there are distinguished five zones, different in terms of external air temperature and insolation. The division accounts for the transitory character of the Poland's climate**,** between a marine climate in the West and a continental climate in the East. The paper deals with energy demand in a typical building, located in different climatic zones. Calculations were made using the BSim computer program, based on the control volume method. It enables the dynamic simulation of energy demand in living quarters and public utility facilities, with the time step of one hour or less. Typical meteorological years were used as the source of climatic data needed in calculations. The thermal characteristics of the apartment's envelope fulfilled the requirements which have been binding in Poland for newly designed buildings since 2014. Two versions of building partitions were adopted: massive and lightweight, and the flat was rotated 45° to the cardinal points of the compass, in order to check how the results depend on various input parameters. The calculations showed diversification in energy demand resulting from external conditions, and revealed the factors which are most important for the energy characteristics of the building.

Keywords: Energy demand in buildings, Typical Meteorological Years, computer simulations.

1. Introduction

In order to establish a reliable manner of assessing the energy performance of buildings, standardized sets of climatic data, corresponding to multiannual outdoor conditions, are applied. These data can take different forms, depending on the adopted method of calculating energy demand.

The degree-days method was the first one which allowed energy demand to be linked to the conditions of the external environment [1]. It assumes steady-state heat transfer in partition walls, taking - as a base temperature - the temperature of the state of equilibrium achieved when a building does not require heating and its heat losses are compensated with solar gains and internal heat gains. Calculations require a minimum range of climatic data which are relatively easy to obtain, i.e.

average daily temperatures of outside air. Modifications to the method allow a number of degree-days to be determined when just average monthly temperatures and the distribution of daily averages as compared with the monthly average (standard deviations) are known [2, 3].

Later stationary methods use a broader range of climatic data, such as air temperature and solar radiation intensity, in the form of long-term averaged monthly or annual parameters. These methods also assume steady-state conditions of heat transfer in building partitions, and a constant, in most cases arbitrarily estimated, use of heat gains coming from users or solar radiation. Stationary methods have a very simple way of calculation, which enables an easy and quick evaluation of the energy performance of objects. A simplified treatment of dynamic processes related to the accumulation and release of heat from the building envelope is a good approximation of the real state if we deal with small solar gains or their effective accumulation. In transitional periods of the heating season (spring and autumn), on account of an increased supply of solar radiation, the assumption of a steady coefficient of gains use leads, however, to major errors [4].

A greater accuracy of calculations is ensured by quasi-stationary methods which consider dynamic effects through the empirical introduction of a specific coefficient of the use of gains or losses. This coefficient depends to some extent on climatic conditions (characterized by the proportion of heat gains and losses) and the thermal capacity and thermoinsulating power of the building envelope. Such a manner of calculation is presented by the standard EN ISO 13790 [5], which is also currently binding in Poland. In spite of a better representation of dynamic effects, the accuracy of analyses can be limited by the values of reference factors taken on the basis of the standard [6, 7].

Dynamic simulations, in which thermal balance concerns short time steps (usually not exceeding one hour) and directly takes into consideration heat accumulated and released from the mass of the building, are regarded as the most accurate for determining energy demand [8]. These methods, on account of the high degree of their complexity, basically serve for the purposes of computer calculations and require a very broad range of data describing the outdoor environment. In the majority of computer programmes the data indispensable for carrying out a simulation include: outside air temperature, air humidity, atmospheric pressure, direction and velocity of wind, and intensity of direct and diffuse solar radiation [9]. These parameters must be known for each hour of the period for which calculations are made. Considering the significant costs and great labour intensity of preparing this kind of data, the so-called Typical Meteorological Year (TMY) is introduced, replacing long-term measurement data with a representative period of one year [10, 11]. It contains 8760 hourly records illustrating the course of required climatic parameters.

In connection with the introduction of the duty to obtain energy performance certification for buildings in Poland, the TMYs were worked out in 2004 for 61 localities on the basis of source data collected by the Institute of Meteorology and Water Management (National Research Institute) from 1971 to 2000. The data provide information about, among others: dry-bulb temperature, relative humidity, wind velocity and direction, solar radiation on horizontal and inclined surfaces. The compilation procedure of the TMY was adopted in accordance with the standard EN ISO 15927-4 [12], coherent with the EN ISO 13790 [5]. The most representative months were the ones in which the average values of the variables, their frequency distribution and correlations were closest to the long-term averages. The key parameters for energy calculations were dry-bulb temperature, solar radiation on a horizontal surface and relative humidity. Information on the TMY is available on the website of the Ministry of Infrastructure and Development (http://www.mir.gov.pl).

2. Climatic conditions in the chosen localities

Poland lies in a zone of moderate climate of a transitory character, between a marine climate in the West and a continental climate in the East. In the winter the isotherm system resembles a longitudinal one, and the temperature increases in the western direction. In the summer the isotherm system resembles a latitudinal one, with the highest values in the central part of the country. In the 1970s, five climatic zones were distinguished in Poland in the winter period [13]. These zones are represented by differentiated design temperatures of external air, taken for the sake of the power adjustment of heating systems (Figure 1).

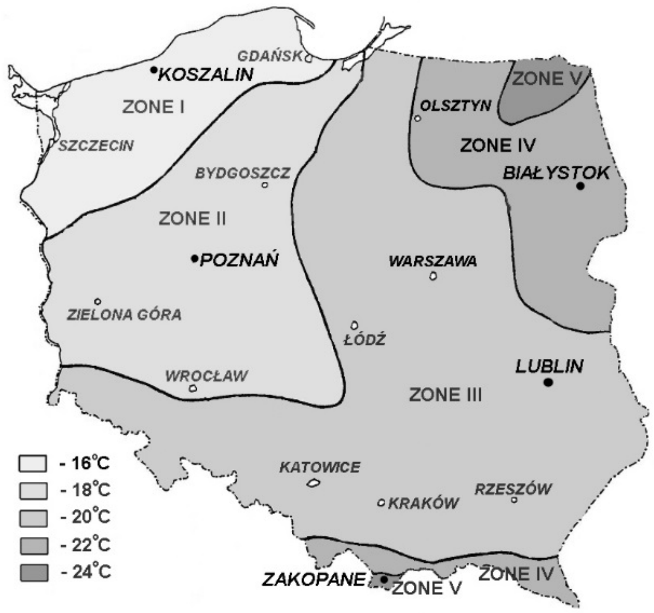

Fig. 1 Climatic zones of Poland and design temperatures in the winter according to [13].

For the purposes of this paper, five localities belonging to different climatic zones were chosen (Figure 1). These are: **Koszalin** (54º 12' N, 16º 09' E), **Poznań** (52º 25' N, 16º 51' E), **Lublin** (51º 13' N, 22º 24' E), **Białystok** (53º 06' N, 23º 10' E) and **Zakopane** (49º 18' N, 19º 58' E). For all these localities, the TMY was worked out on the basis of full, 30-year measurement sequences. In Tables 1 and 2 and in Figure 2 basic climatic data determining energy demand are juxtaposed, e.g. the temperature of external air and solar radiation in the heating and cooling seasons. It was roughly assumed that the heating season lasts from October till May, and the cooling season embraces June, July, August and September. The real lengths of the heating and cooling seasons may differ depending on the building construction and thermoinsulating properties of external partitions, but a uniform division of the year allows climatic data to be more clearly compared.

Table 1: Average temperatures of external air according to TMY [°C]

No.	Zone	Locality	Heating season	Cooling season	Annual average	Min. temp.	Max. temp.	Annual amplitude
1	I	Koszalin	4.4	15.1	8.0	-16.5	27.7	44.2
2	II	Poznań	3.9	16.8	8.2	-15.6	35.2	50.8
3	III	Lublin	3.8	15.7	7.7	-17.7	30.3	48.0
4	IV	Białystok	2.8	15.0	6.9	-17.6	30.8	48.4
5	V	Zakopane	1.7	12.8	5.4	-16.6	27.2	43.8

Table 2: Sums of solar radiation on a horizontal surface according to TMY [kWh/m^2]

No.	Zone	Locality	Heating season	Cooling season	Annual sum	Minimum monthly insolation	Maximum monthly insolation
1	I	Koszalin	389.72	437.63	827.34	16.29	127.87
2	II	Poznań	471.78	489.05	960.83	18.38	149.28
3	III	Lublin	442.26	532.51	974.77	19.79	162.36
4	IV	Białystok	415.30	481.83	897.14	16.04	142.76
5	V	Zakopane	502.94	503.73	1006.67	28.96	146.09

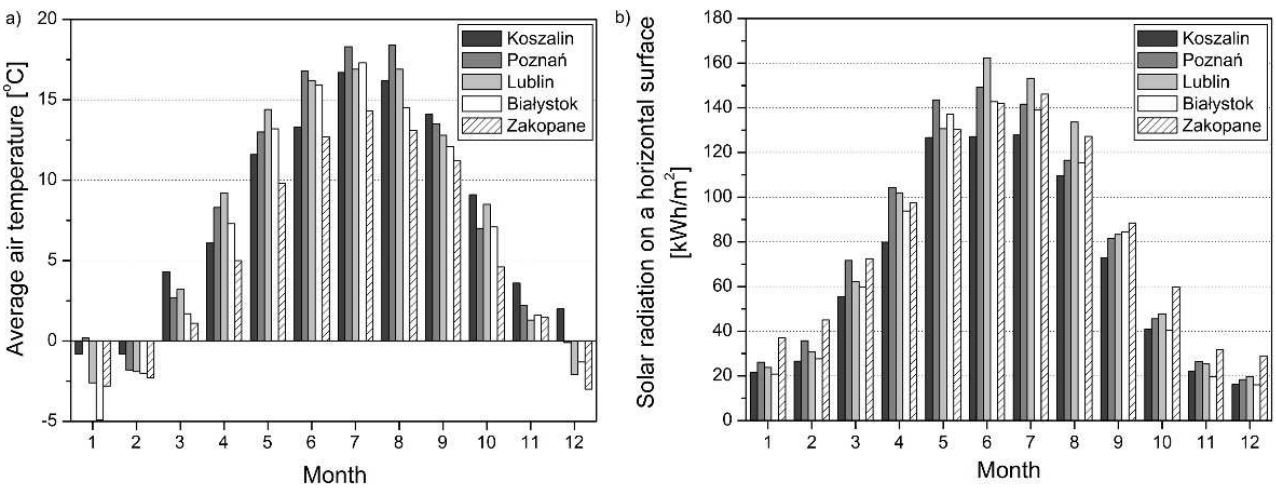

Fig. 2 Climatic parameters in the analysed localities: a) average air temperature, b) solar radiation on a horizontal surface

Koszalin is located close to the Baltic coast, in north-western Poland, in the first climatic zone. The heating season there sees the highest temperatures of external air, combined with the smallest sums of solar radiation intensity. Its predominant part is diffuse radiation, amounting to 74.2% in the heating season and 71.9% in the summer period. The average temperature in the summer period belongs to the lowest from among the selected towns, as does the annual amplitude. The proximity of the Baltic Sea, together with the masses of polar-maritime air strongly influence the climate of Koszalin, bringing about thaws and mists in the winter, and cool and rainy weather in the summer.

Poznań is a city situated in middle-western Poland, in the second climatic zone. The climate of Poznań is characterised by quite high temperatures in the heating season, the highest summer temperatures, and the greatest annual amplitude of temperature. In the heating season the greatest sums of solar radiation are there, while insolation in the summer period is also quite high. In the heating and cooling season diffuse radiation constitutes respectively 67.7% and 70.7% of the intensity of total radiation on a horizontal surface. In the winter and summer periods this region falls under the marked influence of polar-maritime air.

Lublin lies in eastern Poland, within the third climatic zone. The average temperatures in the heating season have middle values, while in the summer period they belong to the highest ones from among the analysed localities. This region is characterised by the highest insolation in the summer, with quite a big share of direct radiation, amounting to almost 37%. This is connected with a frequent inflow of dry air from above Ukraine, and influences of the continental climate.

Białystok is a city located in north-eastern Poland, within the fourth climatic zone. It is characterised by one of the lowest temperatures in both the heating and cooling seasons, and low insolation. Diffuse radiation constitutes approximately 69% of total radiation in the summer as well as in the winter. Masses of arctic and polar-continental air often flow over this region.

Zakopane is situated in southern Poland, in the mountain area. There are the lowest temperatures of external air here, both in the summer and winter, whereas their annual amplitude is the smallest. On the other hand, the conditions connected with solar radiation are very favourable. The annual sum of radiation on a horizontal surface, and the sum of radiation in the heating season are the highest of all the presented locations. The dominant part of this radiation is diffuse radiation (almost 70%), as in the majority of the Polish territory.

3. Calculations of the heating demand

The paper presents an example of a typical apartment in a multi-family building. During the calculations it was assumed, that the building was situated in five different localities within the Poland's territory, so its energy performance was influenced by various climatic conditions. In each of the locations, the flat was rotated by 45° to the cardinal points of the compass, to test the sensitivity of the model's performance to the changing solar irradiation. The calculations revealed which factors are most important for the heating demand of the building, and helped to choose their best configuration in order to minimize energy use.

Calculations of energy needs in the presented paper were made using the BSim simulation program created at Aalborg University in Denmark. This program can be used both for research and project aims. It enables the dynamic analyses of energy demand in living quarters and public utility facilities. Calculations are based on the control volume method, in which structural elements of a building and closed air zones are represented by nodal points with defined physical parameters such as density, conductivity, and heat capacity. For each air zone a separate balance equation is created, including heat flux flowing through the control surface, transmission of solar radiation through transparent elements, heat flux generated by installation systems and transported through ventilation, and infiltration or air exchange between the exterior and the interior of a building [14].

The analysed apartment had a floor area of approximately 74 m^2 and a net height amounting to 2.7 m. The flat was located in the middle section of the building's storey, and it had two opposite external walls with the heat transfer coefficient equal to 0.25 W/m^2K. In each exterior wall there were two 1.5 m x 1.5 m windows, chosen due to the requirements concerning the delivery of minimum daylight (Figure 3). The heat transfer coefficient of the windows was 1.3 W/m^2K, and the total solar energy transmittance of the glazing equalled to 0.63. These values fulfil the requirements obligatory in Poland since 2014. The remaining partitions adjoined the same type of heated rooms and were treated as adiabatic surfaces.In order to check the dependence of results on the room casing, two versions of building partitions were adopted: massive (masonry walls insulated with the ETICS system and reinforced concrete ceilings) and lightweight (wooden framework with mineral wool as thermal insulation). The heat capacity of the envelope, related to the floor area, was 726.0 kJ/m^2K and 255.2 kJ/m^2K, respectively.

Radiation incident on horizontal surfaces was calculated by the simulation program using an anisotropic diffuse radiation model developed by Perez [15], which proved to be consistent with the results of the measurements taken in Poland [16].

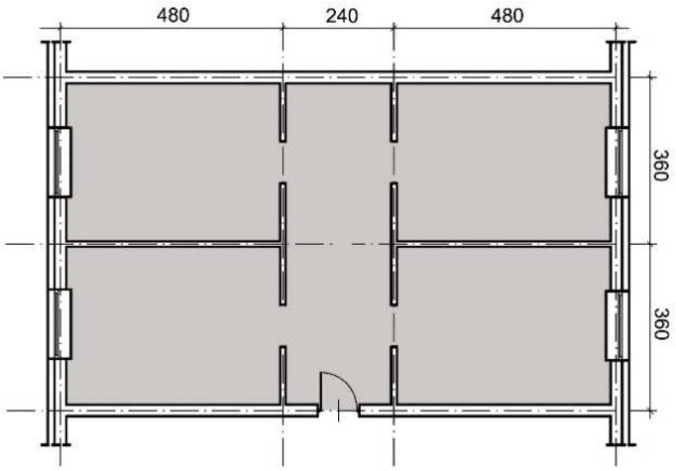

Fig. 3 Plan of the flat simulated in the BSim program (dimensions in centimetres)

Interior gains with the value of 4.5 W/m² and ventilation 0.5 ach/h were implemented. According to national data, these are typical parameters of traditional residential buildings [5, 17]. Rooms can be heated up to 20°C, and the heating system works continuously. Heating demand was calculated without taking into account the efficiency of the installation systems. There were no overshadowing elements near the building or on its elevation. Any influence of residents' behaviour on energy demands (such as drawing the curtains or opening windows) was also excluded from the analysis. These assumptions allow energy demand to be calculated depending only on the parameters of the room casing and outdoor environment conditions.

4. Simulation results

The analyses required altogether 40 computer simulations of the annual cycle of the object's functioning to be carried out. The results are presented in Tables 3 to 6, and in Figures 4 and 5.

Table 3: Heating demand, massive construction [kWh/year]

No.	Locality	Window orientation			
		N-S	NE-SW	W-E	SE-NW
1	Koszalin	1966.45	2082.54	2092.39	1985.87
2	Poznań	1999.53	2138.79	2166.84	2036.09
3	Lublin	2234.42	2336.28	2330.98	2232.08
4	Białystok	2510.23	2621.94	2634.03	2530.63
5	Zakopane	2101.25	2242.97	2212.60	2073.10

Table 4: Heating demand, lightweight construction [kWh/year]

No.	Locality	Window orientation			
		N-S	NE-SW	W-E	SE-NW
1	Koszalin	2011.63	2117.27	2126.39	2026.89
2	Poznań	2059.48	2184.02	2211.44	2090.18
3	Lublin	2289.78	2387.41	2386.40	2291.53
4	Białystok	2543.69	2646.18	2657.14	2560.91
5	Zakopane	2193.17	2323.14	2299.11	2168.40

Table 5: Length of the heating season, massive construction [days]

No.	Locality	Window orientation			
		N-S	NE-SW	W-E	SE-NW
1	Koszalin	188	203	194	190
2	Poznań	165	174	167	161
3	Lublin	171	176	170	168
4	Białystok	183	187	186	183
5	Zakopane	177	174	171	185

Table 6: Length of the heating season, lightweight construction [days]

No.	Locality	Window orientation			
		N-S	NE-SW	W-E	SE-NW
1	Koszalin	214	210	195	189
2	Poznań	197	191	184	172
3	Lublin	192	189	182	179
4	Białystok	203	201	198	196
5	Zakopane	213	198	194	190

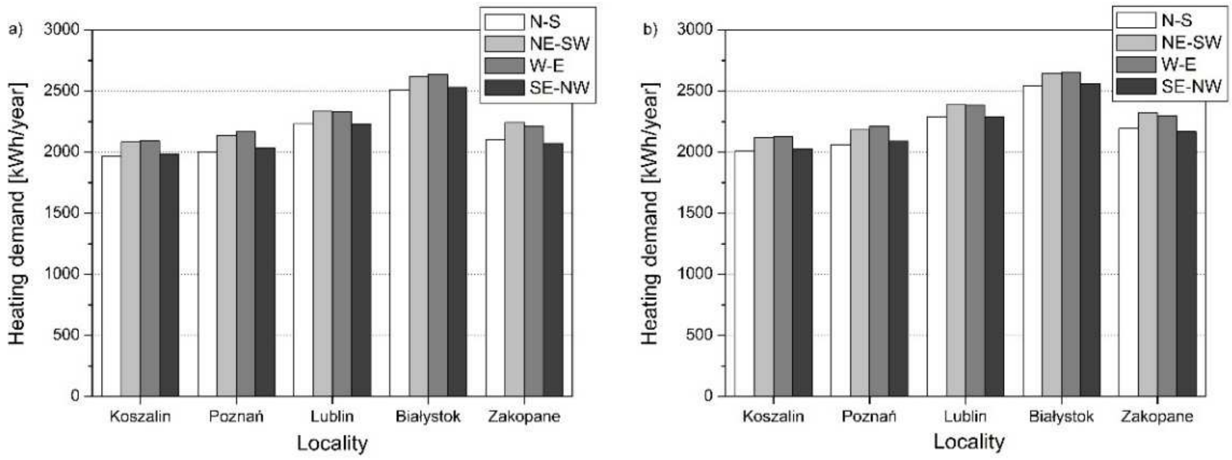

Fig. 4 Heating demand: a) massive construction, b) lightweight construction

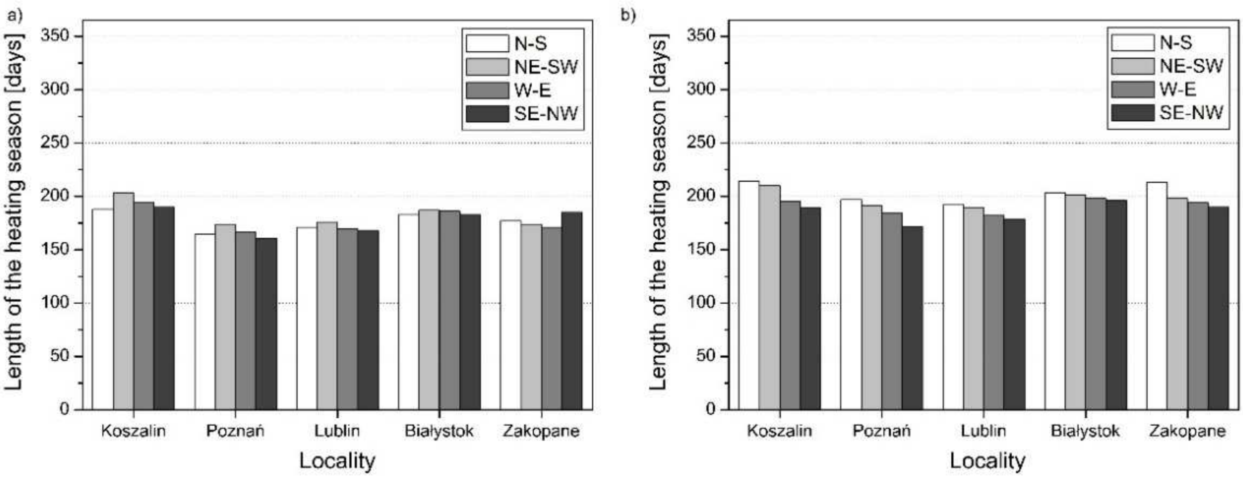

Fig. 5 Length of the heating season: a) massive construction, b) lightweight construction

5. Discussion

Among the analysed localities, the smallest heating demand was observed in Koszalin (belonging to the 1st zone, with relatively mild climate), and the biggest in Białystok (belonging to the 4th zone, with rather severe weather conditions). The increase of heating demand was strongly connected with the decrease of annual average values of external air temperature during the heating season, with the exception of Zakopane. In this mountainous region, despite the lowest air temperature, the solar radiation intensity is the greatest. This is the reason why solar gains compensate for transmission heat losses to a greater extent, and the resultant energy demand is more favourable than could be expected. The heating demand in the particular localities changed in the range of 2% to 28%. The smallest differences appeared between the first and the second zone, and the biggest – between the first and the fourth one.

The connection between energy demand and the external temperature was also reflected in the high values of correlation coefficients, ranging from -0.96 to -0.98 (Table 7). The relationship between heating demand and solar irradiation was slightly weaker, and the correlation coefficients were within the range of -0.75 to -0.92.

Table 7: Coefficients of correlation between demand for heating and temperature and solar radiation intensity, window orientation N-S

No.	Locality	Temperature of external air		Intensity of solar radiation	
		Massive construction	Lightweight construction	Massive construction	Lightweight construction
1	Koszalin	-0.972	-0.972	-0.750	-0.795
2	Poznań	-0.960	-0.969	-0.856	-0.897
3	Lublin	-0.974	-0.984	-0.837	-0.880
4	Białystok	-0.978	-0.984	-0.816	-0.851
5	Zakopane	-0.975	-0.979	-0.880	-0.905

Considering the rotation of the flat to the cardinal points of the compass, in most cases the smallest heating demand was obtained for the windows facing north and south. The vertical plane facing south receives the highest amount of solar radiation during winter. At the same time, the sun elevation angles are small, so the beam radiation strikes the glazing at the angles close to 0º. The smaller the incidence angle, the bigger the solar transmittance of the glazing, providing significant energy gains. In the localities characterized by bigger irradiation (Lublin and Zakopane), the smallest heating demand was obtained for the windows oriented SE-NW, nevertheless the difference between the smallest energy demand and the value determined for the orientation N-S did not exceed 1.4%. These results are caused by the bigger insolation of the elevation oriented towards the south-east during the spring, compared with the elevation oriented towards the south.

The biggest energy demand was, in most cases, connected with the orientation of widows towards east and west. During the winter, the amount of beam radiation reaching the vertical planes facing east and west is relatively small, and the incidence angles are quite big due to the sun's movement towards south. These factors, in connection with smaller glazing transmittance, caused the decrease of heat gains and the increase of final energy demand. In Lublin and Zakopane, the smallest heating demand was obtained for the windows oriented SE-NW, and the difference between the biggest energy demand and the value determined for the orientation N-S did not exceed 1.4%, as in the section above.

The rotation of the flat to the cardinal points of the compass had the smaller influence on the heating demand compared with the location in a specific climatic zone. In the analysed cases the changes did not exceed 8.4%. Since the apartment layout and windows arrangement were symmetrical, this confirmed the big share of diffuse radiation during the heating season.

In all cases, the heating demand was bigger if the lightweight construction of building's partitions was implemented. The decreased thermal capacity of the flat's envelope did not allow the internal and solar gains to be fully utilised. However, this factor had the smallest influence on the energy needs, and the changes of heating demand caused by diminished accumulative properties ranged from 0.9% to 4.6%.

The length of the heating season did not depend on the heating demand itself. The longest heating season was obtained in Koszalin, the locality with rather mild climate and small annual amplitude of external air temperature. The average heating season lasted there 194 days for the building with massive construction, and 202 days for the building with lightweight construction. The shortest heating season was determined for Poznań (massive envelope) and Lublin (lightweight envelope), lasting on average 167 and 186 days. Both of the localities are distinguished by high temperatures and insolation during the heating period, connected with one of the biggest annual amplitude of external air temperature.

The maximum differences between the heating period duration in the presented localities amounted to 29 days, while the differences caused by the change of window orientation and thermal capacity of the flat's envelope amounted to 25 and 36 days respectively. In the flat with massive construction the shortest heating season was observed if the windows were facing north and south or SE-NW (with the exception of Zakopane). If the lightweight construction was implemented, the shortest heating period was determined for the windows oriented towards SE-NW, and the longest – for the windows oriented towards north and south.

6. Conclusion

The results of simulations presented above indicate, that the key factor influencing heating demand is the location of the building and its specific climatic conditions, especially the course of the external temperature. The choice of the climatic zone in which the building is to be constructed usually is dictated by the investor and does not depend on the designer's decision. Other parameters, such as the rotation flat to the cardinal points of the compass and thermal insulating or accumulative properties of the building's partitions, could be chosen consciously in order to diminish future energy use. In the analysed localities, the most favourable conditions are provided by windows facing south, giving the biggest solar gains during the heating period. Deviation from the south direction not exceeding 45º to the east does not produce the adverse effect on the energy balance, and in the localities with considerable amount of solar radiation intensity may even be more profitable. Orientation of the windows turned out to influence heating demand to a greater extent than the thermal capacity. Nevertheless, the implementation of the massive construction enabling to exploit the additional heat gains in a better way is still important for the energy use.

It should be mentioned, that the paper did not fully exploit the problems connected with the shaping of energy demand. Because of the limited range of the presentation, the issues such as the window size or total solar energy transmittance of the glazing were excluded from the analyses. The author hopes, however, that the presented research may contribute to the more conscious buildings' design process and the diminishing of the heating demand to the necessary minimum.

Acknowledgements

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Commercial areas achieving the zero emission goal using the potentials of electric mobility: The eCar-Park Sindelfingen

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Summary

The eCar-Park Sindelfingen aims at delivering carbon neutral heat, electricity and mobility to its settling companies. To reach this aim, symbiotic relationships between electric mobility and renewable energies are identified and established: Electricity oversupplies will be buffered in battery electric vehicles (BEV) and fed back in times of undersupplies. If managed appropriately, the concept requires less installed capacities of renewable energies, which leads to decreased investment costs.

Keywords: eco-industrial area, electric mobility, energy management, fleet management, mobility demands

1 Introduction

1.1 Problem

Attended by stricter environmental regulations, consumer demands for ecologically more compliant products and services have risen for decades [1]. In a multitude of industrial and commercial branches these frame conditions have evoked vast efforts to supply the growing markets. For example, a multitude of product systems has been examined holistically in life cycle assessments (LCA), environmental product declarations (EPD) or carbon footprints (CF), which are usually complex and expensive. Another remarkable kind of effort aiming at greener products is the establishment of eco-industrial parks (EIP), which took place at commercial and industrial areas throughout Europe and the world. EIPs are generally characterized by a common management of at least environmental and resource issues [2]. Hence, cooperation between companies on site is indispensable: required material flows are used in closed-loop systems or bundled, energy flows are fed from renewable sources or cascaded, as by waste heat recovery [3].

However, transport demands usually entail fixed environmental impacts in companies and commercial areas, which are hardly manageable. Whilst single measures to reduce transport induced environmental impacts are usually cost intensive and often ineffective, comprehensive measures tend to fail due to their multi-stakeholder approach [4]. It lacks a concept that makes integrated, sustainable mobility economic feasible and transferable – independent from a park's location.

1.2 Aims of the eCar-Park Sindelfingen

Closing the gap described above is the overall aim of the eCar-Park Sindelfingen. A mix of different renewable energy sources and combined heat and power (CHP) generation will provide of electricity, heat and cold. In conjunction with the electricity buffering function of battery electric vehicles (BEV), the eCar-Park achieves a widely grid-independent operation.

The focal point of our research is the role of BEV, which, by making their batteries available to the park's energy management, could either act as electricity buffer storages or assume a role as control instruments – while still meeting the transport demands of the settled companies. Hence, it is essential to synchronize the parameters 'fleet size' and 'downtime' (i.e. being connected to a charging station) with the mobility needs of a variety of branches.

Besides the technical implementation, organizational, economical and legal questions are in the centre of interest. On the one hand, business models will be developed for utilizing the feasibility of vehicle2grid systems. On the other hand, legal burdens shall be identified and solutions proposed to feed the process of legislation with real life demands.

In reality, the implementation of cooperation in EIP via a top-down approach fails in most cases [5]. Hence, the concept of eCar-Park Sindelfingen will, when transformed into an integrated business model, serve as a basis to implement more sustainable mobility and energy structures in EIP via a bottom-up approach.

Car fleet managers name the lack of business models as the highest barrier to acquire BEV [6], while experts see the central accelerator for developing the electric mobility market explicitly here: in municipal and corporate car fleets [7].

The transferable concept of eCar-Park Sindelfingen will

- enable more sustainable economic activities in commercial areas,
- educe grid relieving effects, notably in grids with high shares of renewable energies, and,
- demonstrate options for developing the electric mobility market.

The integration of monetary stimuli possibly promoting the acquisition of BEV is encouraged: Within the framework of the eCar-Park's business model, corporate users (companies) as well as private users (employees) could generate revenues by providing their vehicle batteries as buffer storages.

1.3 eCar-Park site description

On ten hectares of fallow land in Sindelfingen-Darmsheim, approximately 100,000 m² of factory halls – consisting of units up to 23,000 m² – and 50,000 m² of total office areas will be built. See Figure 1 for a visualization of the eCar-Park.

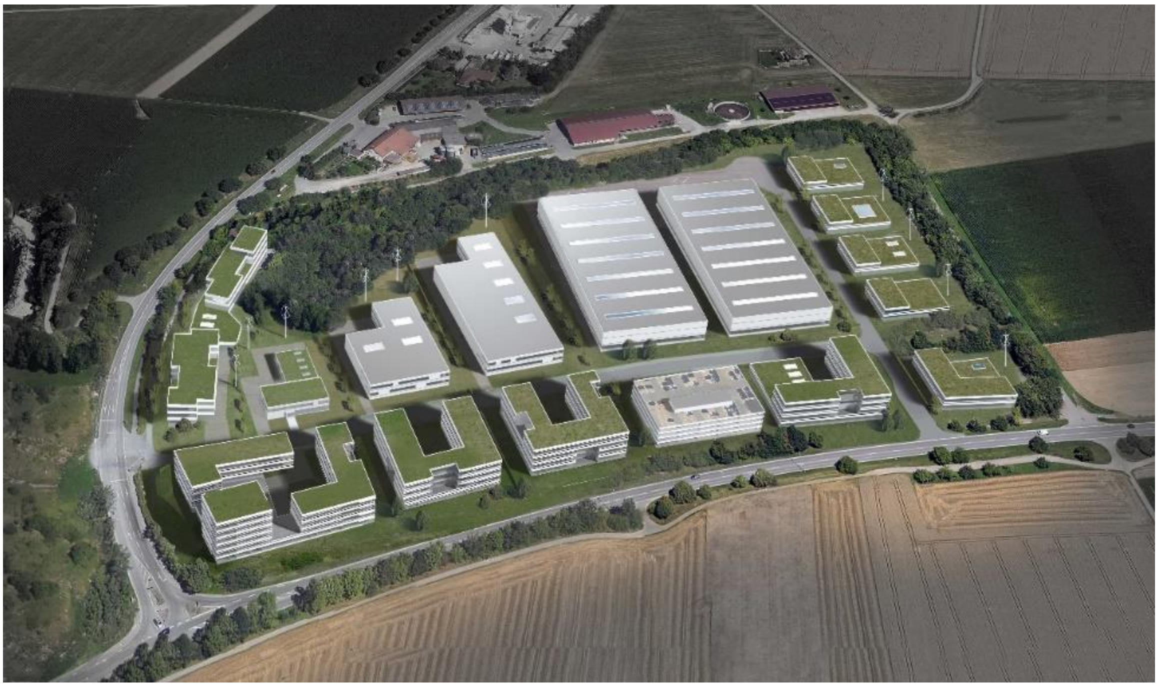

Figure 1: Visualization of the eCar-Park Sindelfingen [studio|3, 2015, www.s3a.de]

The settling companies shall benefit in different ways: Ecologically from decarbonized energy and mobility systems and economically from long-term stable prices for electricity, heat and transport.

2 Methodology

2.1 Energy concept

Companies settling in the eCar-Park Sindelfingen will purchase heat, cold, electricity and mobility by a significantly low carbon emission factor. BEV retrieve the potential to serve as a buffer storage for fluctuating renewable energies: Electric oversupplies are stored in BEV and discharged in times of undersupply. An appropriate management presumed, less installed capacities of renewable energy facilities are required, so the invest declines. BEV serve as a control instrument to absorb peak demands or even provide grid autarky during longer periods of undersupply to a certain extent. Calculating this extent is our research subject.

The park will be supplied by electricity from photovoltaics, wind power and biomass; CHP motors generate basic load. The energy management shall be able to be run heat led or power led. Heat pumps deriving geothermal heat can provide additional heat. A neighbouring stone quarry allows access to cooling water. Figure 2 shows a schematic overview of the energy concept.

Currently the eCar-Park's energy concept is being developed as a simulation tool, based on known hourly load curves of a variety of branches or kinds of workplaces (e.g. offices, labs, gar-ages etc.). Accordingly, energy generation is simulated by using known parameters for the site such as hours of sunlight, intensity of radiation and wind availability. The focal unknown for a realistic simulation, however, is the available size of the mobile electric storage on an hourly basis and as a function of a company's size, branch and tasks.

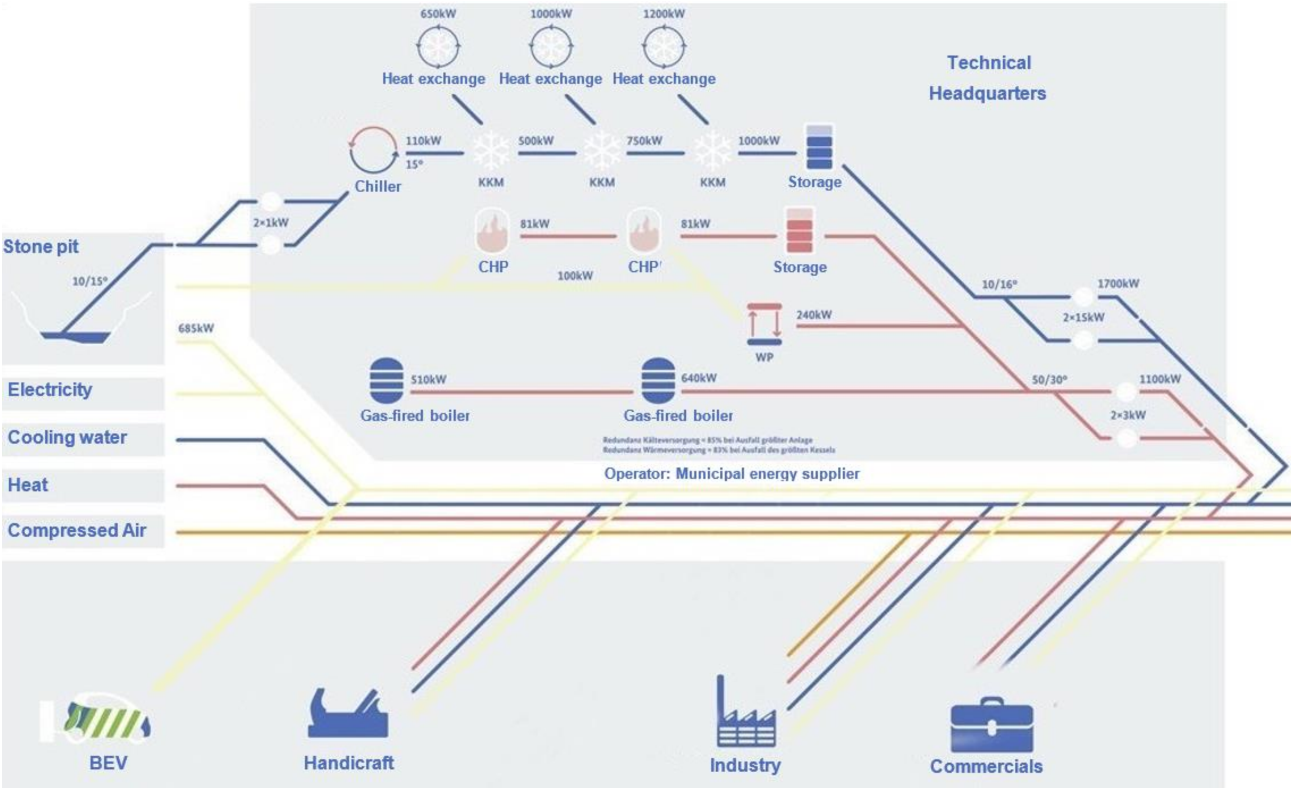

Figure 2: Schematic overview of the eCar-Park Sindelfingen energy concept [EFG 2015, http://www.engineering-facility-group.de]

2.2 Fleet sizes and mobility demands

The total fleet size of the eCar-Park Sindelfingen will consist of three separate BEV-fleets: (A) A central pool of vehicles is provided to the settled companies by the park operator. In addition, companies themselves (B) and employees (C) own BEV to a growing extent as the market is emerging. They are assumed to make their batteries available to the energy management, since bidirectional charging in micro cycles increases the life span of lithium batteries [8]. Furthermore, companies and employees profit from refunds; this might be attainable, as their batteries act as invest-free storages to the energy management. Table 1 categorizes the three BEV-fleets by central characteristics.

Table 1: Characterization of the three BEV-fleets considered in the energy system

	A. Park BEV-fleet	**B. Corporate BEV-fleet**	**C. Employee BEV-fleet**
Expected fleet size	small	medium	big
Expected size of buffer storage size	small	medium	big
Predictability of downtimes at charging station	medium	low	high
Downtimes at charging station assumable	by night (except sharing is opened)	by night (except open for private use)	by day (except multi-shift operation)

2.2.1 Corporate BEV-fleet

Corporate fleet sizes and compositions are currently being collected in dependence of a company's branch, its portfolio, size (number of employees), and its transport connections. By combining these data with existing logbooks, the – fossil fueled – mobility demands of companies will be derived.

Based on the mobility demands, we can simulate the eCar-Park energy management with arbitrary company compositions. As a result, the park wide number of internal combustion vehicles (ICV) in each relevant vehicle category is derived, including aspects such as yearly mileage and expectable downtimes – which are used for charging, buffering and discharging. Furthermore, considering the driving profiles, ICV are identified which allow a one-to-one replacement with BEV. It's been showed by Weiss et al., that ca. 29% of corporately used ICV could be substituted by BEV via minor adjustments [9]. The replacing BEV are stored in the system as buffer storages in accordance with their driving profiles, energy consumptions and battery sizes.

The following formula illustrates, how the State of Charge (SOC) for any BEV is calculated for each hour of the year. Depending on the respective BEV-model and its known charge capacity, the potential to charge and discharge for any hour of a year is derived. Finally, knowing the amount of BEV in downtime (connected to charging infrastructure), the cumulative buffer storage is summed up.

$$SOC_{Fzg}(t) = SOC_{Fzg}(t_0) + \left[(VC * CD) + \sum_{t_0}^{t} E_{Charge} - \sum_{t_0}^{t} E_{Decharge} \right] * \frac{1}{\eta}$$

SOC:	State of Charge [kWh]
VC:	Vehicle consumption [kWh/km]
CD:	Covered distance [km]
E:	Energy [kWh] – *Park external charging actions require a separate consideration. For simplification they are combined here with park internal charging actions.*
η:	Overall efficiency (charging, battery, vehicle) – *The charging efficiency differs from the discharging efficiency. For simplification they are presumed to be identic.*

The concept's transferability on other industrial areas depends on the number of acquired branches or operational tasks, fleet sizes and mobility demands.

2.2.2 Employee BEV-fleet

Employees usually park their private vehicles before they start to work and leave the company's parking space right after they finish working. Hence, the available buffer storage size in any hour of the year is predominantly dependent on the company's number of employees. Combined with the easily available knowledge about periods of shifts of the settling companies, a rough estimation will be possible with moderate effort.

However, a vast number of factors influence the buffer storage size of the employee BEV-fleet. Of course, the highest influence results from the assumed percentage of BEV. It can either be the real percentage of BEV licensed in a region or country (baseline scenario), or be assumed to be higher due to the park's BEV-supporting energy system and its economic incentive. Furthermore, branches and jobs (e.g. sales) exist where employees use company cars in their private life as well. Currently, we assign these vehicles to the corporate BEV-fleet, but for programming reasons it might become necessary to assign them to the employee BEV-fleet. In any case, these double used cars might show minimal availability to the energy system – and their mileage might exceed the potentials of BEV anyway. Finally, several minor factors such as flexitime working hours, employees leaving by car during lunch breaks or employees commuting by bike under certain circumstances can add up throughout a company and the whole park and have a vast influence on the predictability of the buffer storage size.

2.3 Project status

In 2014, first renewable energy facilities (photovoltaics and small wind power) and the central charging station were installed, see Figure 3. In the same year, the BEV-fleet owned by the park operator (fleet A) was equipped with four cars. Currently, the project consortium uses these BEV so that we can analyse their real life power performances (efficiencies, charging capacities, ranges during summer and winter).

The organizational framework had been created by establishing the Concept Centre Blue Business (COBIS), an institution managing relevant eCar-Park issues. At present, the main task is marketing the commercial and industrial areas.

With the development plan currently being finished, the construction phase starts in 2016 with the infrastructural development. Companies will start settling on-site in summer 2016. The park construction phase shall be finished in 2017.

Meanwhile, the fleet sizes and mobility demands of companies are analysed as described before and fed into the energy management tool. Accompanying research aims at further increasing transferability aspects of the project: By utilizing quantitative and qualitative methods of social sciences, the acceptance of the concept is evaluated and monitored as the park is being settled.

Figure 3: Central charging station and the first BEV of the eCar-Park Sindelfingen [Schäfer GmbH, 2014, www.schaefer-unternehmensgruppe.de]

2.4 Funding note

The project eCar-Park Sindelfingen is funded by the Federal Government in the framework of the program "Schaufenster Elektromobilität" and the Baden-Württemberg Ministry of Environment.

3 Discussion

3.1 Economic aspects

The quantification of potential cost advantages for car owners is the focal aspect of our research, since the overcoming of economical burdens is seen as the most relevant leverage to spread electric mobility [7].

In the eCar-Park Sindelfingen ecological and economical frameworks are developed and quantified, which may significantly influence the procurement of companies and by that strengthen the market development of electric mobility.

BEV sales appeals are expected to arise for private car owners, as the drivetrain specific incremental costs will shrink due to revenues from battery storage and higher battery life spans.

Bidirectional charging of electric vehicles is currently not established on the market. First large-scale tests to describe the potential of electric cars as buffer storages in smart grids ran for example at BTU Cottbus-Senftenberg (Project "e-SolCar"), where discharging was technically realized with specially developed BEV and charging infrastructure. In eCar-Park Sindelfingen, the installed technology shall be further developed into stable economic structures. A huge advantage to reach this aim is the very strict spatial delineation of a commercial area. Additionally, the ownership structure on the site itself is another significant relief, as the implementation is achieved from one source.

3.2 Technical aspects

An interesting option is the integration of battery swap systems. First providers already have successfully established such systems in the market. Utility vehicles are equipped with batteries, which can be exchanged at swapping stations with relatively low effort. One station stores around 10 batteries that could support the energy management system in a substantial way, as they sum up to a relatively big storage which is partially stationary. As a side effect, range burdens could be overcome by installing satellite stations around the eCar-Park.

3.3 Framework

During the process of technical implementation, legal and fiscal constraints impeding an optimal and widespread implementation of vehicle2grid-concepts will be identified. Recommendations will be derived that shall be fed into the ongoing processes of standardization and legislation.

Prospectively, integrated mobility also involves the substitution of routes that are not mandatorily requiring car-utilization, with alternative vehicles such as bicycles, pedelecs or electric cargo bikes. Those partially electrified mobility solutions cannot reasonably be integrated as buffer storages due to low battery capacities, but their use can lead to longer downtimes of BEV and therefore play a more important role in the energy management system.

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Conceptual Design and Development of a Study Program in the Field of Climate Protection Management

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Summary

One of the key factors for sustainable built environments is not only a successful municipal or corporate climate protection strategy but also a well-trained team of professional climate protection managers (CPM) that operate as networkers and coordinators. Due to the enormous complexty of the field of work of climate protection managers, it is highly advisable to provide an educational branch, which is specialized on the different technical, social and methodical requirements in the field of climate protection management.
To meet the increasing demand of professional climate protection managers in town councils and companies the Institute NOWUM-Energy and the Solar-Institut Jülich of the FH Aachen University of Applied Sciences, Germany, developed the project “CPM@FH-Aachen”.

Keywords: Climate Protection Management, education, teaching methods, university, sustainability

1. Introduction

Private households, economy, industry, traffic and services generate the highest amounts of CO_2 emissions. A network of European cities, counties and municipalities has formed a climate protection alliance, which is aiming to reduce the exhaust of greenhouse gases in urban spaces by 10% every five years and totally up to 50% till 2025 compared to 1990 [1]. But often it is shown that these set goals cannot be reached within the planned periods or even at all [2]. Not least to save costs, town councils and companies around Europe make an effort to reduce their carbon footprint. Multiple possibilities and ideas for climate protection are already available, but there is yet a lack of climate protection managers with sufficient technical and economic background knowledge to guarantee a fast implementation of climate protection strategies. Furthermore, climate protection managers are supposed to have a high degree of motivation and convincibility to fulfill the com-

plex every-day tasks. They are supposed to manage technical problems as well as to interact and moderate between different social groups and representatives, like e.g. city councils, politicians, companies or citizens.Town councils and companies are permanently looking for qualified professionals to implement their climate protection strategies. Yet, study or advanced training programs, that directly address prospective climate protection managers and are able to cross the gap between technical and social education are very rare.
The institute NOWUM-Energy and the Solar-Institut Jülich of the FH Aachen University of Applied Sciences, Germany, developed the project “CPM@FH-Aachen” to counteract the skills shortage.
Climate protection management is an interdisciplinary task, which can be performed for example by architects and mechanical engineers as well as by civil or electrical engineers. To generate a sufficient amount of access points for climate protection managers, one part of CPM@FH-Aachen is to develop curricula and teaching materials for a two-semester specialization course “Climate protection management”, which can be modularly implemented into several already existing bachelor programs (Fig.1). For bachelor graduates who want to get a deeper insight into climate protection management, additionally a master degree program has been developed, which will be approachable for bachelor graduates of miscellaneous study branches. Graduates of the master course will be fully equipped with the necessary know-how to guide, support and coordinate citizens, companies and city councils competent and effectively with different climate protection campaigns.

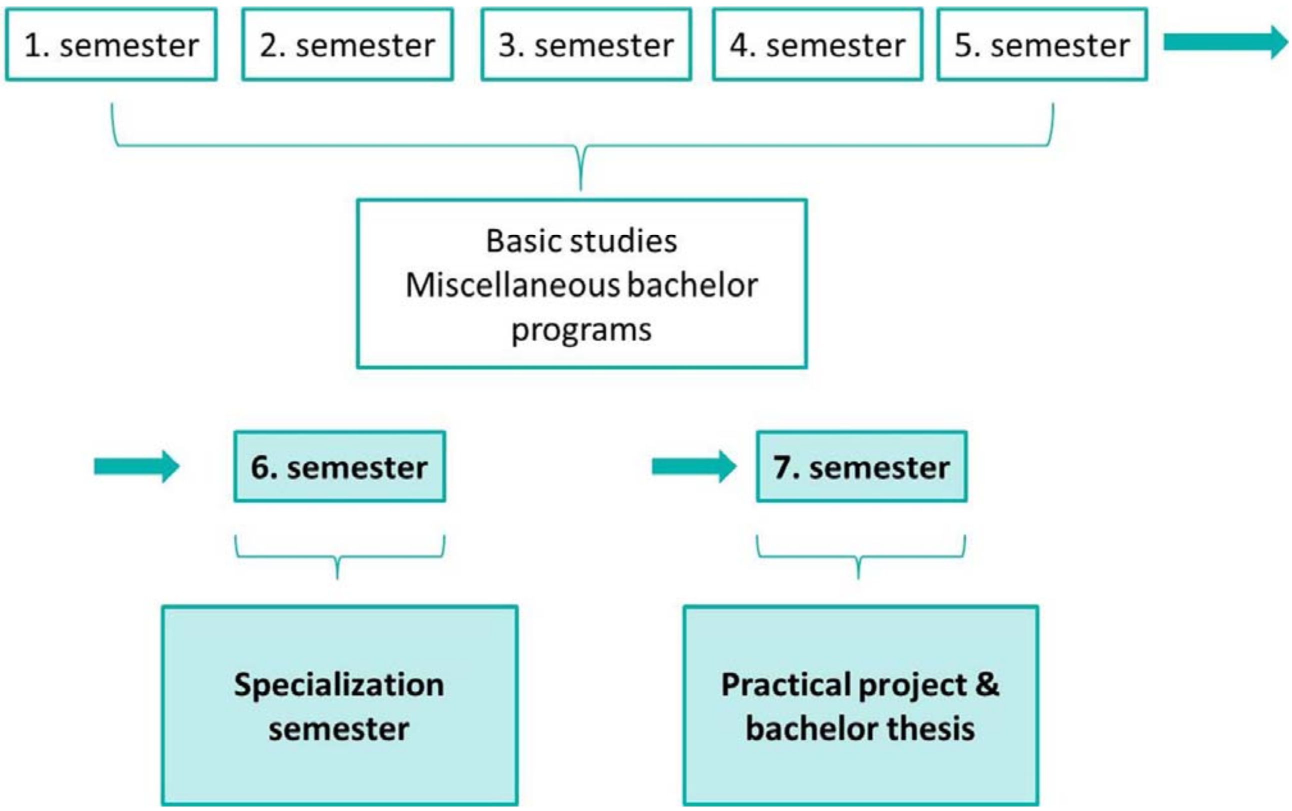

Figure 1: Implementation of the specialization course into already existing bachelor programs

The primary goal of the project is to develop a degree program, which is balanced on the necessary technical, social and methodical topics and enables motivated people to become climate protection managers. Thus, NOWUM-Energy and the SIJ want to satisfy the constantly growing demand for experts in the field of climate protection management. Right from the start one goal of the project was to interact closely with the relevant target audiences like climate protection managers, universities and representatives of municipal adminitrations to generate a study course, which meets the demands and requierements.

To generate a range of courses that precisely match the requirements of the practical work life of climate protection managers, a detailed qualification profile for climate protection managers has been compiled. More than 1000 climate protection managers, which are already professionally active, have been interviewed about job-related challenges and their background of education.

The result of this survey of town councils and climate protection managers is that the following individual skills are indispensible in the every-day work:

- Project development & management
- Managing the climate protection process
- Public relations and communicating with non-administrative parties
- Engineering basics, no “expert skills”

Based on this, teaching modules for the two-semester bachelors specialization course and for the master course will be developed. The teaching modules for the bachelor specialization course will be designed in a way that they can be easily integrated into already existing bachelor programs in a modular manner. Due to its specific design and structure, the master program on the other hand will be accessible for students with various qualification backgrounds.

In late spring 2015, when the development of the teaching modules and curricula for the bachelor and the master programs has been completed, they will be presented to different German universities and colleges, which will have the opportunity to integrate them to their existing study programs.

2. Methodology

The demands on the skills of municipal climate protection managers are characterized by a high degree of interdisciplinarity. Among these demands, climate protection managers have to face in practice, are communication skills to mediate information to different target groups like, e.g. experts, municipal politicians, media representatives, consumers or investors. Furthermore, a profound comprehension of economic relationships, knowledge of relevant technology branches and the interconnectivity between these branches as well as knowledge of municipal administrative structures are essential. Only very few towns and municipalities in Germany have employees being skilled in all of these fields in one person. The complete job specifications for qualified employees for climate protection management in Germany have not been investigated in detail yet. Thus, the first part of the project was a nationwide survey of towns and municipalities regarding the duties and activities of already active and future climate protection managers. The surveyed climate protection managers have been interviewed about the following topics:

- Educational background,
- Task priorities in the every-day work life of climate protection managers,
- Approaches for improvement of the necessary skills to perform the work as a climate protection manager (professional training, special training, learning by doing),
- Relevant topics for a study course in the field of climate protection management.

The developed questionnaire has been delivered to about 1.400 German cities and municipalities. The return rate was about 10 percent. Some of the results are presented here: As shown in Fig.2, climate protection manager cannot be assigned to one specific branch of education or training.

The majority of the interviewees has been trained in the fields of geographical sciences, environmental sciences, landscaping or urban and regional planning. Apart from that the interviewees graduated in many diverse fields of natural sciences and humanities. This insight led to the conclusion that many different educational preconditions have to be considered, when developing a study course in the field of climate protection management, especially for a specialization semester, which shall be included into already existing study programs.

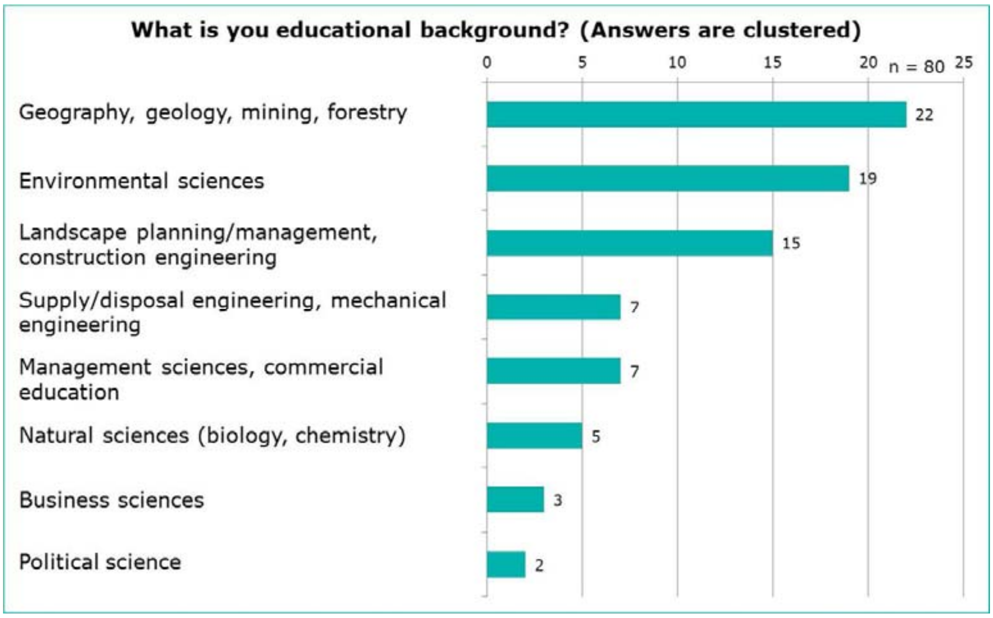

Figure 2: Educational background of climate protection managers

In addition to that, the interviewees have been polled which skills are absolutely indispensible to comply with their current tasks and responsibilities as a climate protection manager and should therefore been included as a topic in a study program for climate protection managers from their point of view. Fig. 3 gives an overview of the topics, which have been chosen by the majority of the interviewees.

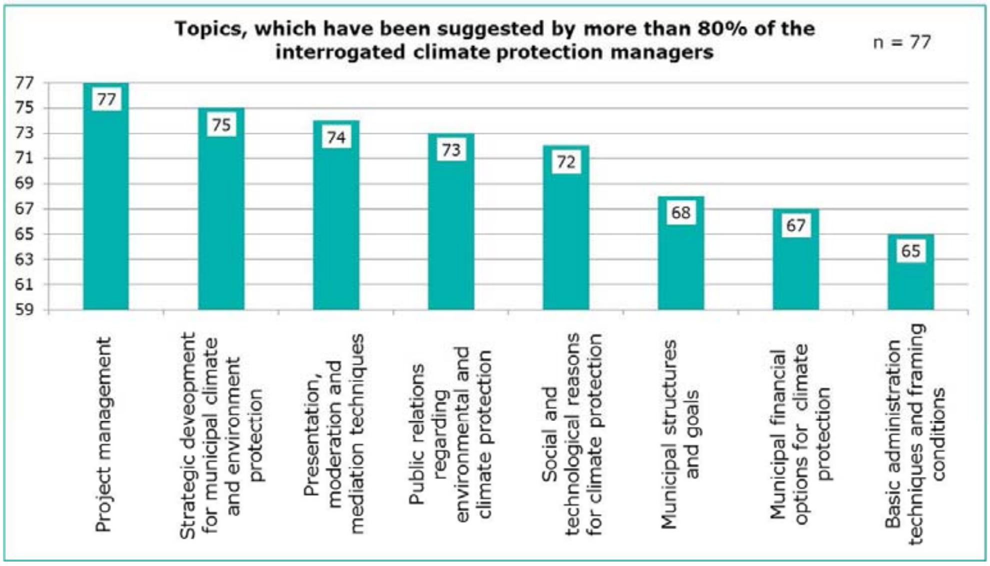

Figure 3: Indispensable topics for educational program for prospective climate protection managers

It can be seen that relevant topics mainly derive from fields like administration or management as well as social sciences. According to the interviewees a general basic understanding in special natural scientific topics is also relevant, but no “expert knowledge”.

Based on these results a precise requirement profile for the teaching and learning content of the planned study courses has been developed. Four core competencies have been determined, which shall be imparted in the planned study courses and which will be the basis for the development of the teaching modules. The four core competencies are:

- Technical basics / climate & energy
- Municipal structures and boundary conditions
- Mediation / Moderation
- Project development and -implementation

These core competencies are the basis as well for the Bachelors specialization course as for the master program.

3. Results

3.1 Integrative bachelor specialization course “Climate Protection Management”

The structure of the planned bachelor specialization course is designed such that students will be able to choose the developed contents subsequently to their basic study after the fifth semester (Fig. 1). First part of the specialization course will be a regular semester, with an amount of 30 ECTS credit points or a workload of 900 hours, respectively, which contains most of the developed teaching modules. The bachelor course will be completed in the 7th semester, including a practical project and the bachelor thesis. The final semester will also contain 30 ECTS credit point or 900 hours of workload, respectively. Thus, a total workload of 1,800 hours will be prepared for the students, to be trained in the four core competencies.

It is planned to integrate three different types of teaching modules into the curriculum of the specialization course. On the one hand there are so called compulsory modules, which are mandatory for every student. Then there are elective and complementary modules that students can use to design their curriculum individually. This provides the opportunity to learn complementary skill without renouncing essential skills.

In total following eight compulsory modules are planned for the specialization course:

- Overview of climate protection management
- Personality development
- Project management
- Public relations
- Climate protection concepts
- Practical project
- Bachelor thesis
- Colloquium

Within these eight modules the established main core competencies will be mediated. After graduation in these modules, the students will be able to:

- Comprehend the necessities for global and regional climate protection management
- Identify and evaluate the consequences of climate change on at regional level

- Identify provisions and strategies for climate protection and adaption and to evaluate the consequences
- Get an overview of the range of duty and assignments of climate protection managers be aware of the role model and the responsibilities of this field of profession
- Identify the general structure and content requirements of a climate protection concept
- Apply different balancing strategies and evaluate energy and emission flows
- Understand calculation methods to identify potential for greenhouse gas reduction as well as approaches of scenario development
- Identify the aims and methods of public relations as well as the relevance of public relations in the day-to-day work of climate protection managers
- Develop campaign strategies and identify the according target groups
- Describe the approach during the implementation of climate protection strategies

Following four teaching modules will be available as elective modules:
- Energy economy and management
- Energy efficiency
- Energy system technology
- Renewable energies

The intent of the elective modules is to mediate the technical background of climate protection management. According to the developed curriculum, students will be able to integrate at least three or also, depending on the educational background, up to all four technical teaching modules into their studies.

Finally, to reach necessary amount of ECTS points, students will be able to choose from a list of four complementary teaching modules. These modules cover following topics:
- Municipal structures and boundary conditions
- Project administration/handling and project funding strategies
- Rhetoric, communication and presentation techniques
- IT basics

Additionally to the improvement of the communicative skills, these modules intent to give a deeper insight into the day-to-day work of climate protection managers. Experience shows that some of the complementary modules provide a general additional benefit for the students for example to facilitate the preparation of the bachelor thesis.

Fig. 4 gives an overview of the amount of credit points of each module. During the two-semester specialization course students will achieve 40 ECTS points from the compulsory modules and at least 16 ECTS points from the elective modules. Missing credit points to reach the required amount of 60 ECTS points can be achieved with the complementary modules.

Fig. 5 gives an example, how the different compulsory, elective and complementary modules can be combined to a complete two-semester specialization course with a total amount of 60 ECTS points. A combination like this can be used for example in natural sciences bachelor courses, where technical topics have most likely been part of the stage studies and more focus on social skill would be advisable.

The FH Aachen University of Applied Sciences, Germany, firstly offers the specialization course “Energy and climate protection management” as part of the newly structured seven semester

Mechanical Engineering bachelor course in the department of Energy Technology since winter semester 2014/15. So far, each winter semester more than 140 students have enrolled for the Mechanical Engineering bachelor course. The specialization course will firstly be offered at summer semester 2017.

Bachelor specialization course "Climate protection management"	
Required amounts of ECTS-points after two semesters	60
Compulsive teaching modules	**ECTS**
Overview climate protection management	3
Personality assessment / analysis	2
Project management	5
Public relations	5
Climate protection concepts	5
Practical project	10
Bachelor thesis	8
Colloquium	2
Total	**40**
Elective teaching modules	**ECTS**
At least 3 of 4	
Renewable energies	4
Energy efficiency	4
Energy system technology	4
Energy economy and management	4
Total	**16**
Complementary teaching modules	**ECTS**
Rhetoric, communication and presentation techniques	2
IT basics	2
Municipal structures and boundary conditions	2
Project administration/handling and project funding strategies	4
Total	**10**

20 ECTS points in total from these two module groups

Figure 4: ECTS points for the developed teaching modules for the bachelor specialization course

6th Semester			
	Module	**ETCS**	**Total credits**
Compulsory mod.	Overview climate protection management	3	10
	Personaltiy assessment / analysis	2	
	Project management	5	
Elective & compl. Modules	Renewable Energies	4	20
	Energy efficiency	4	
	Energy economy and management	4	
	Rhetoric, communication and presentation techniques	2	
	Municipal structures and boundary conditions	2	
	Project administration and project funding strategies	4	
7th Semester			
	Module	**ETCS**	**Total credits**
C. Mod.	Climate protection concepts	5	10
	Public relations	5	
Final	Practical project	10	20
	Bachelor thesis	8	
	Colloquium	2	

Figure 5: Example for a possible combination of compulsory, elective and complementary modules

3.2 Master program “Climate Protection Management”

Parallel to the development of the bachelor specialization course, a curriculum for a master course in the field of climate protection management has been developed, which defines study objectives, extent, structure, types of courses as well as admission and examination requirements. Furthermore the master course has been developed for two different concepts: on the one hand as an in-service part time course an on the other hand as a full-time course.

Based on the core competencies and the teaching modules, which have been developed for the bachelor course, a set of compulsory and complementary teaching modules has been established that covers the defined study contents and can be used according to admission requirements and temporal structure.

The general assumption during the planning process was that the master course will consist of 3 semesters with 30 ECTS points for each semester, which makes a total amount of 90 ECTS points. Similar to the curriculum development for the bachelor specialization course, compulsory and elective modules have been developed for the master course. This will make it easier for universities and colleges to integrate this course to their already existing structures, regarding the particular admission requirements. Furthermore students will be able to plan and design their courses more individually.

While technical topics are mainly part of the elective modules in the bachelor specialization course, they will be an essential part of the compulsory modules in the master course. In total, the following compulsory modules have been developed for the master course:

- Climate protection competence
- Personality development
- Renewable energies
- Energy efficiency
- Project management
- Municipal structures: Basics & administrative structures
- Energy economics & management
- Project financing and funding
- Municipal structures: committees and interfaces
- Public relations
- Climate protection concepts
- Master thesis
- Colloquium

To reach the necessary 90 ECTS points, students can additionally elect from the following complementary modules:

- Accounting
- Legal basics
- Energy system technology

3.3 E-Learning

In line with discussion about lifelong learning as well as about improved compatibility of family and job or family and education, respectively, every modern study program should offer the possibility to receive teaching materials not only during classroom seminars but also from other sources in a digital form. Thus, one part of the project CPM@FH-Aachen is to support the developed bachelor specialization course with an elaborated e-learning concept, exemplary for the compulsory teaching module “Climate protection concept”. This e-learning module will be developed, following a guideline, which has been developed by the Institute for Energy and Environmental Research (IFEU) in Heidelberg, Germany[3]. The e-learning module will be compiled that students will be able to acquire lecture materials online. Furthermore, video sequences of the lectures will be produced, where lecture issues are being explained and discussed by means of explanatory examples.

4. Discussion

As the results of the survey among already professionally active climate protection managers in Germany showed, climate protection management is a highly complex and demanding field of profession with a high degree of interdisciplinary. Climate protection managers need to be trained in many different fields of expertise. Therefore, when developing a training program for prospective climate protection managers in form of specialization course, which shall be implemented into already existing bachelor courses, it would be not advisable to focus only on one study branch. To come up to the prerequisites and conditions of different study branches, it was aimed to offer content, which is absolutely unique and indispensible for the work as climate protection manager. All indispensible content has been elaborated in form of compulsory modules, which should be used for every bachelor course. These are topics mainly focussing on social skills, like personality assessment or public relations. According to the surveyed climate protection managers, basic technical skills are also important, but not on an expert level. Furthermore, technical topics are often already part of the stage studies in many bachelor courses. Therefore, technical topics like renewable energies or energy efficiency have been shifted to complementary modules so that every university or college can choose, which of these topics should be offered, according to their own prerequisites.

Regarding the master course the results of the survey have shown that the general interest of climate protection managers in advanced training is very high. Many of the interviewees stated that they would be interested in participating in a master program in the field of climate protection management. However, the results have also shown that the demand for an in-service part-time master course will probably be higher.

First efforts in contacting other universities or colleges, to discuss a possible integration of the developed materials into their existing structures have shown that the awareness of the importance of this field of education is often very low, yet. Therefore, no efforts in communicating the necessity of the topic climate protection management have to be spared.

5. Conclusion

Two study concepts for a two-semester specialization course for bachelor programs and a three-semester master course for prospective climate protection managers have been planned and developed successfully. Curricula and teaching materials, including an exemplary e-learning module have been elaborated.

In the next steps the public relations and communication with other universities and colleges will be intensified. In workshops with representatives of educational institutions, municipal administrations and climate protection managers the results of this project will be presented, publicly discussed and disseminated. Additionally, universities and colleges will be contacted directly or invited to discuss with us a possible implementation of the developed programs into their structures.
Continuative projects will have to deal with a more detailed development of the teaching materials for the master course, especially with regards to e-learning modules, and also with analyzing the demands for educational programs in the field of climate protection management in other European countries or even in global context.

6. Acknowledgements

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- National Climate Protection Initiative

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Constructions suitable for recycling

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Summary

Fifty-two percent of the total amount of waste generated in Germany comes from construction waste. Modern buildings are often characterized by using complex building materials, which are either inseparable connected to each other or there are scarcely recycling options.
Even with the selective dismantling, this complexity leads to a poor recovery of valuable materials. Well-designed buildings have a significantly best ease of repair in case of damage or renovation and also contribute to a reduction in construction waste, which are removed after demolition in a waste incineration plant or deposited into landfills. This garbage reduction leads to a more effective use of secondary raw material and substantially higher resource efficiency.
Nevertheless, the subsequent dismantling does not get much attention when planning a building. Moreover, planning tools are required to have a better overview. These constructions can be judged according to the selected material, as well as actual time and effort involved in the dismantling process; the aim is finding solutions to get trend-setting recycling alternatives.
In order to reach a planning level application, catalogs based on appropriate criteria can be developed; these will be a helpful tool for engineers and architects. In addition, a consideration of a dismantling plan should be considered as part of the planning and construction phases of the schedule of services and fees for architects ans engineers (HOAI).

Keywords: Resource efficiency, Dismantling, Recycling, Urban Mining, Construction

1. Introduction

In Germany, approximately 550 million Mg of mineral resources are yearly being removed and used for the production of building materials [1]. Thus, construction and building material industries are responsible for 60% of the resources, and 35% of energy consumption in Germany [2]. Estimations regarding to the German residential inventory of the year 2010 show that, about 10 billion of Mg mineral building materials, such as brick and concrete, are being used as construction materials, as well as approx. 220 million Mg of woods and in particular, 100 million of metals. Furthermore, it is predicted that in the year 2025 this amount of material usage will increase by a further 20% of the actual amount [3].

The resource management agency in Vienna has calculated for the building and infrastructure facilities in Austria a potential of resources of 4,500 kg of steel per capita, likewise, approx. 340 kg of aluminium, about 200 kg of copper and nearly 40 kg of zinc [4]. Referring these numbers to the population of Germany, there is about 365 million Mg of steels, approximately 28 million Mg aluminium, nearly 16 million Mg of copper and around 3 million Mg of zinc. (Fig. 1) This corresponds to about a total monetary value of about EUR 175 billion.

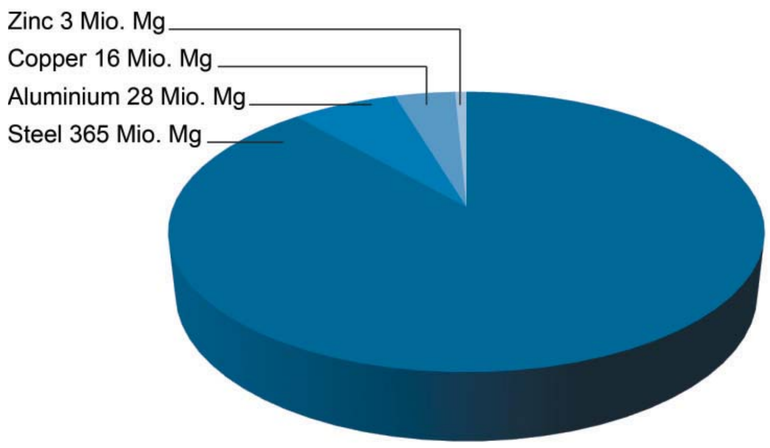

Fig. 1 Amount of metals in Germany used for construction and infrastructure (according to [4])

Considering the background of the respective situation of resources, which is becoming scarce and expensive, resource deployment is becoming increasingly important to the deposits created in buildings and infrastructure facilities.

Current trends, such as, the demographic decline in Germany [5], miniaturizing households [4] as well as emigration from East Germany [6], [7] – are main points that explain the fact of the approx. 1 million empty homes in Germany. There is a great potential of finding recyclable materials in those empty establishments (metals and minerals) which can be obtained through restoration measures, such as urban mining. Moreover, investigations about the manufacture of recycled concrete have shown that in addition to metals, minerals can also be highly recycled, [8]. Recycled construction and demolition waste mixed with natural gravel and crushed stones can be reused in construction fields. The city of Zurich can be used as an example; here public procurements require a minimum amount of recycled concrete as part of the contract [9].

2. Materials and methods

2.1 Waste management situation

Looking at the current disposal situation in the construction sector, new constructions, renovation and demolition of buildings produces a great amount of waste in Germany with about 192 million Mg per annum in terms of volume; this is the largest waste stream based on the total waste in Germany [10]. According to the latest monitoring report initiated by the recycling economy and construction of the year 2012, there was a total of approximately 91.2% of recovered waste. (Fig.3)

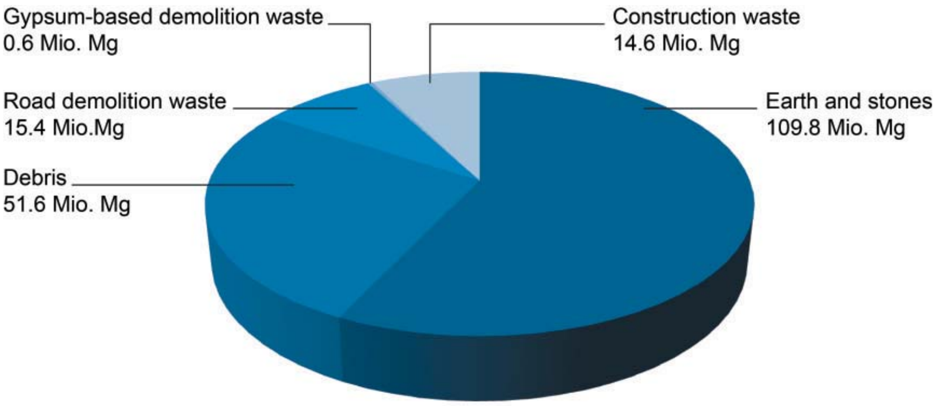

Fig. 2 Amount of construction waste in Germany in 2012 (according to [11])

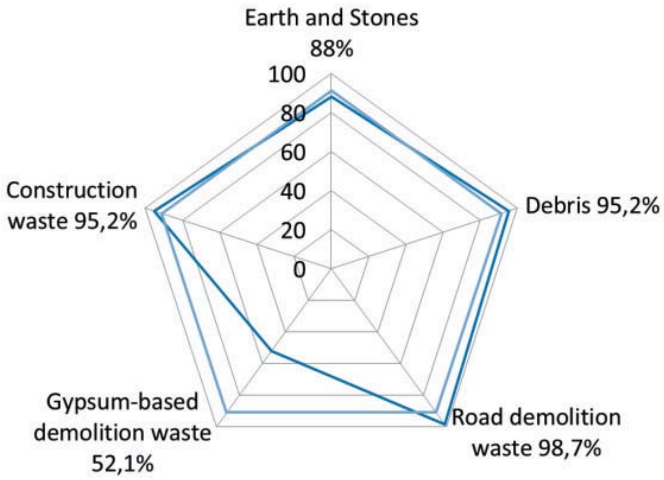

Fig. 3 Recycling rate for different kinds of construction wastes in Germany in 2012 (Average recycling rate: 91,2%) (according to [11])

The applicable recycling rate at a national level will be significantly exceeded to a 70% by the year 2020. A high-quality recycling of construction waste in buildings is thus usually not associated. While some parts of the construction wastes are energetically exploited in waste incineration plants, the recovery of mineral construction waste is taken as general rule, which is also related to the material quality, and subordinated measures in road and scenery construction, in landfills or in the mining industry as a filling material [11].

The country-specific recycling regulations for mineral waste are based on the notification of the 20 Regional Working Groups focused on waste management (LAGA), the so-called Mantelver-ordnung is intended to be replaced in the future through a governmental regulation (being imple-mented by the end of 2016). The regulation includes three parts, which are: an amendment about the groundwater regulation, the replacement of the construction material regulation and an amendment of the Federal soil protection. Due to the replacement of the regulation about con-struction materials and the amended regulation about soil protection, the exploitation of secondary mineral resources in technical structures should be indeed controlled, in particular, the backfilling on construction sites.

These specifications are very controversial between the parties, because the construction industry is concerned and fears about the significant limitation on recovery options as well as the currently thresholds, such as, the permissible PAH and sulfate level content on mineral waste [11].

Unless the material quality of mineral wastes meets the requirements needed for recycling, the disposal into landfills is not a long-term solution, because Germany has very limited landfill capacity.

Hence, the quality of mineral waste will continuously decline, due to constructions built on the late 20th and 21st century, which are mainly characterized using a variety of complex construction materials (e.g. vacuum insulated panels and thermal insulation systems (ETICS)), that are inseparable merged together, or for which there are currently any recovery options.

According to a current study, approximately 9 million Mg of exterior insulation and finishing system (EIFS) were used between 1960-2012 [12]. This trend was due to increasing demands on thermal insulation, new ideas, and the demand for faster construction periods. The material composition of these systems and also some components, such as, flame retardants, HBCD, used since 2015, interfere with the future recycling quality of material flows.

2.2 Recycling barriers at construction and demolition activities

Construction and demolition activities are characterized by a variety of different and responsible actors of various levels of action (planners, contractors, building material producers, demolition companies) which are involved with different tasks (e.g. general contractor or sub-trades). (Fig.4)

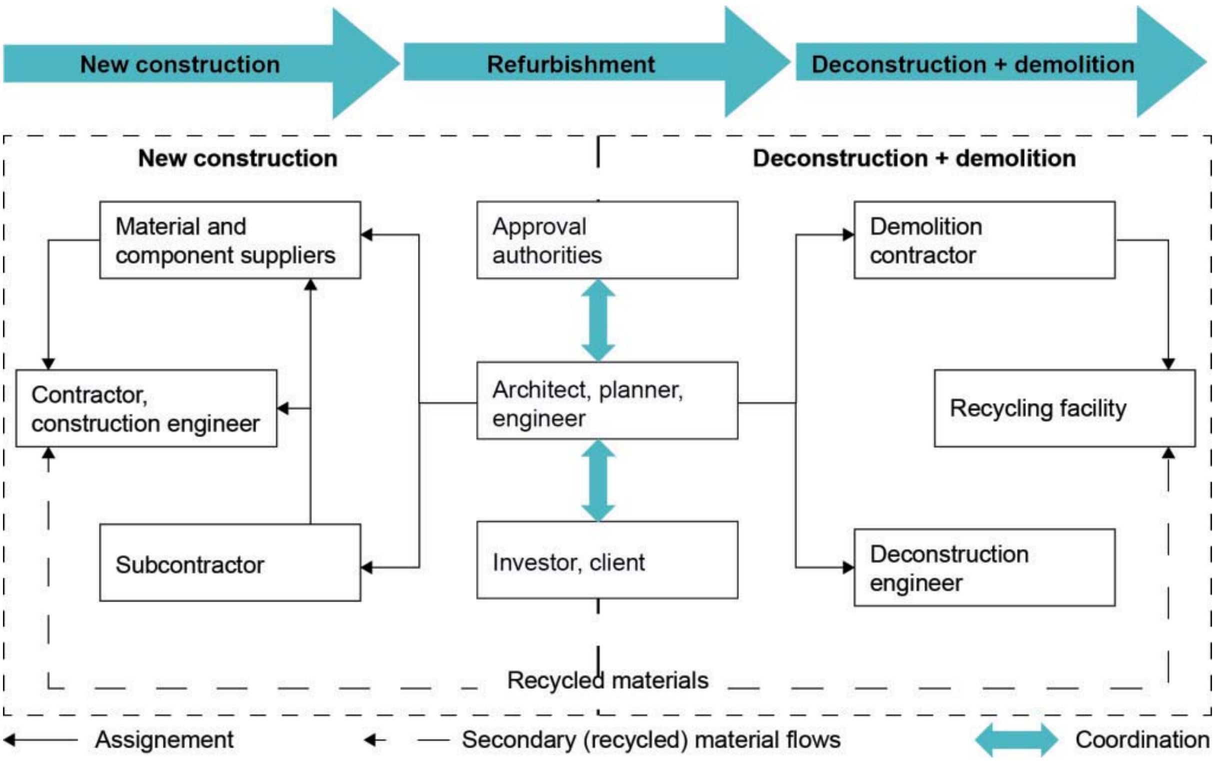

Fig. 4 Overview of stakeholders involved in the construction and demolition of buildings

The insufficient consideration of the recycling concept in the planning of buildings is obtained for the individual levels of action related to:

Table 1: Recycling barriers at the various levels of action during construction and demolition work

Operation level	Obstacle
Planning/Design/ Construction	Lack of an overview about the existing recycling options / environmental friendly dismantling and design. Lack of awareness regarding the need to be part of the dismantling plan, which is normally according to the owner's budget.
Development of building materials	Lack of (economic) incentives, in which the focus is not really on rewarding the development of an environmental friendly dismantling but on other areas (functionality, design, etc.) Costs / Competition.
Dismantling and recycling	There is an absence of information regarding the installed construction materials. High costs generated by complex compounds of different materials / construction materials will not be reimbursed. There are an increasing proportion of unknown and / or new construction materials impeding the production of high-quality secondary raw materials.
Administrative framework, (Issuing-) Authority	There is a deficit of (legal) specifications and potential solutions which interefere with the increase of resource productivity.

All the involved participants are trying to develop efficient solutions. However, this topic refers to singular activities, such as the European Gypsum Industry, which started with the project „GtoG (Gypsum to Gypsum) – From production to recycling“ at the beginning of 2013 or the return system for aluminium offered by system providers and extrusion press works of construction profiles [13], [14]. Unfortunately, such distinctive approaches don't have enough impact on the terms of resource productivity.

2.3 Preliminary Results

The summarized situation of resource flows in the construction industry can be described as follows:

- There is a steadily grow of potential resources in buildings and diverse infrastructures.
- Getting high quality recycled material is difficult when there is an increment of complex building materials or inadequate constituents.
- There is not a nationwide legal regulation available regarding terms of recycling. Even though there is a prearrangement regardings those terms, the exact content and introduction of these are still very controversia.
- There is not a nationwide legal regulation available regarding terms of recycling. Even though there is a prearrangement respecting those terms, the exact content and introduction of these are still very controversial.
- Even though the material quality of mineral wastes does not meet the requirements needed for recycling, the disposal into landfills is not a future solution, because Germany has very limited landfill capacity.

- The idea of recycling is currently not the main focus on the planning of construction projects due to the variety of participants and responsables involved.

3. Results

3.1 Constructions suitable for recycling

Buildings likely to be dismantle, provide a better reparability and demolition when there is a damage or remediation case, it grants higher resource efficiency by reducing waste deposition into landfills or incineration plants.
Planning tools are required to allow an appropriate evaluation. Constructions should take into account considering the material choice as well as dismantling costs; new alternatives should be set against evaluated and popular standard methods.

There are planning tools that can be integrated for a sustainable construction (BNB, DGNB. V.s.). Here, are some useful planning questions:

- What would be a fair definition and evaluation of dismantling?
- How can recyclability be objectively described? What can be a reasonable and applicable tax base for this purpose?
- What does a construction suitable for recycling means in term of costs for construction and demolition?
- How can we develop an awareness on the involved parties of the construction sector?
- At what point and at what stage the dismantling process makes sense for planning and construction?

Moreover, a few structures are being investigated and evaluated as part of a Master's thesis at the Muenster University of applied science. Hence, there are some recommendations that can be applied on those structures, e.g. [15]:

- Structural joints should use the same kind of composite material, construction aggregates.
- Use of detachable structural joints.
- Use of curtain walls or exterior insulation finishing system, use of bolt joints, use of loose laying instead of glued, fixed connections.
- It is mandatory to keep up with a documentation of the material flow as well as the construction.

To achieve a further application level, there are some aspects that should be developed in order to have suitable criteria that can be useful for architects and engineers related to this area; furthermore, it is important to incorporate catalogs describing qualitative assessment of the dismantling process, the recyclability and the recovered material stream of the current structural planning.

Construction catalogs (most of them don't include demolition planning aspects) have handy planning tools that are commonly applied in the praxis [16], [17]. These tools are effective for getting fair results, which can be used in the future as planning foundations for dismantling and maintenance operations.

3.2 Incorporation of dismantling and recycling in sustainable constructions

The certification system of the German Sustainable Building Council (DGNB) was introduced in the year 2009, as well as the evaluation system for sustainable buildings (BNB) of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), the dismantling process and the ability of separate construction materials have a direct impact on the classification of the technical quality of a building [18].

The criteria used in this case have been updated several times. The new system version 2015 for Sustainable Building of the DGNB promises brand new indicators for assessing the dismantling process:

- Recycling-oriented building material selection: it is rated on standard components, whether the component can be reused or recycled as higher - or equivalent raw material or construction material.
- Recyclable Construction: It is evaluated in terms of standard components, whether the component can be removed without affecting or destroying the building and whether it can be separated according to the material type

Estimated standard components for these indicators can be found in the following calculation tool [6].

A differentiated classification system, such as an accordance modeled after the law on closed cycle management, is not currently planned. (Fig.5) Dismantling costs or disposal costs are not considered.

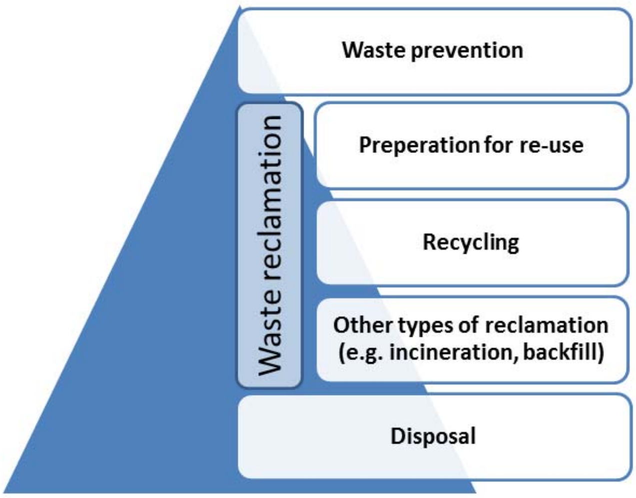

Fig. 5 Hierarchy of waste disposal according to the German Closed Substance Cycle Waste Management Act (according to [19])

3.3 Dismantling Concept

An additional approach is the introduction of a mandatory dismantling concept (including estimated costs). This could be created during the planning phase or at the end of the usage period.

Moreover, a further development of recycling and recovery technologies is necessary to achieve a successful progress in the dismantling concept at the end of the usage period. However, it is still unclear about what extend creating a detailed picture of a possible building according to the usage phase or the acceptance of any technical or financial expenditures.

Accordingly, a better resource efficiency can be achieved through the establishment of an appropriate concept in the planning and construction phases (phases 2-8) (Fig.6).

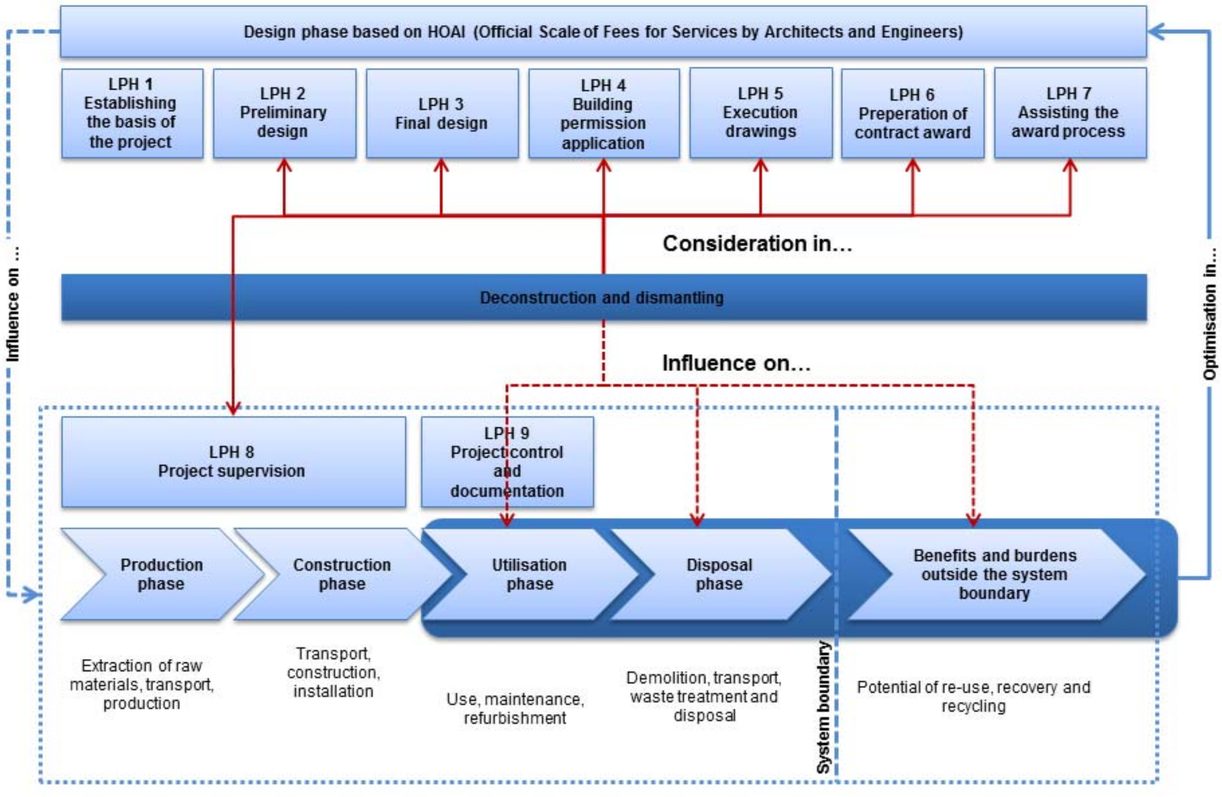

Fig. 6 Influences and consideration of deconstruction and dismantling [20]

At this stage, all essential information, such as construction plans, design drawings and stockist, can be relevant data of the current installed materials. Additionally, the development of a dismantling concept creates incentives for promoting a recycling environmental friendly construction.

4. Discussion

In pursuance of recovering raw materials contained in buildings, it is necessary to have access to the building planning, the dismantling phase and the recycling quality of used materials and their correspondent documentation related to the planning. This requires, practical planning tools that allow a fair assessment of dismantling, solvability as well as separation of compounds and recovery of the components in the design and planning and in order to provide economic planning suggestions for architects and engineers.

Table 2: Measures to improve the utilization of resources from the field of construction

Operation/ Participant	Required measures
Planning/Design/ Construction	Consideration of a dismantling plan in context of the HOAI. Orientation and planning assistance in the form of detailed catalogs including assessment of individual compounds related with deconstruction, recycling and sorting accuracy. Education and training planning teams on approaches related with sustainable construction with emphasis on resource-oriented designs.
Development of buildings materials	Development of new connection techniques related with the dismantling process. Incentive for manufactures to develop resource-oriented construction techniques and to include them in their product portfolio.
Dismantling and recycling	Detailed documentation and information regarding the removal of the installed building materials. Classification of structural components according to the compatibility between material, detachability, dismantle and recyclability. Categorization of components of a building type, service life and dismantling.
Administrative framework, planning authorities, legislation	Required documentation in the form of a building pass. Integration of design deconstructions as a planning service in the HOAI. Incorporation of recommendations for design deconstructions in the Building Material Recycling Manual of the German Ministry of Environment (BMUB) in order to increase the quality of recycled construction materials. Integration of requirements and approaches related with recycling-environmental friendly constructions in green building certification schemes. Integration of dismantling applicable structures in building information modeling BIM.

5. Conclusion

In conclusion, the instruction of architects, engineers and planners about resource-efficient building is an integral part of a qualitatively and quantitatively recycling of anthropogenic deposits. Introducing a dismantling process in the planning stage will improve the quality of the recovered raw materials. There are strategic points that support planning groups with the implementation of resource-oriented constructions:

- Conceptual understanding about orientation and planning assistance.
- Administrative development of a building pass and the integration into building information modeling BIM.
- Integration of the deconstruction process in the HOAI in recognition of the increased of benefits and expenses.

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Full Paper

Cooperative Housing Models in Zurich. Or: Can sustainable, affordable and socially-mixed housing be realised together?

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1. Introduction – initial situation, question and methodology

In growing city regions in which a tensed housing market situation exists socially underprivileged households have particular difficulties to find or to keep living space. On the one hand this is generally the case but applies on the other hand even more for living space with high residential quality or quality of life. Residential quality refers beside the flat also to the building, the residential environment, the infrastructure and services near to the flat as well as social networks and neighborhoods. For some time the technical discussion has treated increasingly the topic how the need of low-income households can be considered more intensively and who can contribute to the challenge how in town more social housing and more affordable living space can be provided again. Since particularly in large cities clear increases in rent prices have been registered [1] in their result more far-reaching segregation processes are feared. Because the rental housing stock takes over an „important supply function for low-income households and problem groups“ [2], in Germany demands increase to reanimate social housing and to strengthen the corporate element in the housing politics [3] [4].

The present contribution deals with corporate forms of housing in view of low-income households. Many cities have municipal housing companies that have a supply mandate for low-income households. But beyond that living in a cooperative offers for the members, who are likewise owners and tenants, a relatively great security because a disposal against the will of the owner is not possible. Therefore, the cooperative is an attractive form of housing especially for groups who are underprivileged on the housing market. Nevertheless, the legal form of the cooperative, originally developed from the self-help movement, as well as other housing companies, must assert its position in the market. However, even if cooperatives must act economically, the corporate objective does not lie in contrast to "classical" market-oriented housing associations with priority in the making of profits, but to act in the interests of the cooperative’s members and to promote these [5].

Against the background of this housing policy debate, it is worth to take a closer look at the practice in Switzerland and evaluate present experiences, especially in the city of Zurich, where the housing market on the one hand is very tight, and on the other hand it is characterised by a strong position of cooperatives. The cooperatives stand up there actively for affordable housing. In view of the tensed housing market situation in Zurich a series of new, self-managed housing cooperatives or umbrella organizations of existing cooperatives have been established. These have often simultaneously set sustainability and social mixing to the target next to affordable housing. In this context, the question arises, what special features characterize the cooperative housing in Switzerland? What innovations pursue the housing cooperatives in Zurich in terms of affordability, sustainability and social mixing? Can this "triad" be realized together? These questions shall be examined based on the still young housing project in the Hunziker Area. [6]

Methodical approach: The paper is based on inquiries of the specific situation in Switzerland and Zurich (literature, internet and material research). Furthermore, guided interviews to the case study Hunziker Area in Zürich with relevant actors of the cooperative „mehr als wohnen“, like Monika Sprecher (director) and Stefan Hilbrand (project manager of citizen participation till summer 2014) and experts like Margrit Hugentobler, ETH Wohnforum Zürich, were important for obtaining additional information and assessments.

2. The Swiss Confederation - cooperative tradition and general conditions

Switzerland has a far-reaching tradition of cooperative thinking on the local level. The model "cooperative" as a legal entity has a history of more than 150 years [7]. The origin of the model is indeed in Germany (currently more than 2,000 housing cooperatives with approximately 2.2 million homes in inventory [8]). The first housing cooperatives in Switzerland emerged in the result of bad living conditions in urban locations in particular between 1890 and the First World War. A second wave of establishment and construction of cooperatives followed after the Second World War, as housing shortages predominated. From the 1980s, numerous new establishments of housing cooperatives with self-government character came in addition. [9]

Switzerland is a tenant country, which is particularly evident in Zurich. With only 8.1 % ownership [10] the majority lives in Zurich to rent or in a housing cooperative. There are in Switzerland around 1,500 housing cooperatives (in total around 150,000 dwellings, 8.8 % of the total housing stock of Switzerland). 18 % of the dwellings in Zurich [11] belong to more than 100 housing cooperatives (for comparison: percentage of cooperative dwellings in Germany: around 10 %). This stake is – under the premise of trying to "create more affordable housing" – to be expanded [12]. The municipal government of Zurich is, as through a bill decided by national referendum, commissioned to "increase the stake of non-profit dwellings by 2050 from currently 25 % to one-third of the rental housing stock" [13]. The cooperative is a legal entity that is based on democratic principles, on self-responsibility, self-management and self-help of the cooperative members. Who lives in a cooperative has a say in the fortunes of the cooperative. With cooperative housing the following advantages are attributed [3] [5] [14]:

- type of housing between ownership and rental, which quasi represents an insolvency-proof business form,
- comparatively cheap form of housing,
- the financial commitment in the form of the cooperative stake is significantly lower than individual property,
- cooperative housing provides safe living with lifelong usage or residential rights,
- direct influence on the management of the cooperative capital. The rights to a say and rights of co-determination open up the opportunity, among other things to influence the development of housing prices and measures on the object.

3. Housing market and urban development policy in Zurich

3.1 Population development and land use

Switzerland is, related to the population, a growing country. Currently the growth rate amounts to about 4 % [15]. The proportion of the foreign population lies at 22.8 % (status 2012). The largest group of migrants comes from Italy, closely followed by Germans, representing in urban areas like Zurich currently a majority. The settlement area in Switzerland has increased within the last 24 years around 584 square kilometers. Between 1985 and 2009 approximately one-seventh of the land area has been redesigned. These figures led, among other things, in the wake of the latest update of the Swiss Spatial Planning Act (RPG) to a refusal of additional land consumption– subsidized by a nation referendum. [16]

This has also consequences for Zurich. As the largest Swiss city with over 400,000 inhabitants (status 2014, Zurich city; Zurich Metropolitan Area: 1.6 million inhabitants) Zurich is growing continuously. As a consequence the demand for dwellings rises and in accordance for new housing construction as well as replacement of buildings and corresponding for renovation and expansion of existing buildings.

3.2 Development of the housing market

In consideration of the growth in population a very tense housing market exists in the entire metropolitan area of Zurich. In the city of Zurich the housing situation has been marked for many years by a strong demand surplus and gentrification or the displacement of old-established residents by the exorbitant rising prices in the housing market“. Rents have risen steadily in recent years (from 2004-2012 by about 10 % [10]), with the result that there is "housing shortage".

Low-income and socially underprivileged households are particularly affected by this housing market situation. Among 7.6 % of the population the disposable household income lay in 2011 below the absolute poverty line (Poverty danger line is in Switzerland at around 15 %; compared Germany: 15.8 % [15]). Among the household types people in one-parent families (21.9 %) are most often affected by poverty. In addition, the poverty rate is raised with individuals (singles) less than 65-year-old (11.4 %) as well as more than 65-year-old (25.7 %). Risk groups of poverty are further children, families with many children and persons of foreign nationalities. [15]

As a consequence of the growth in population house building took place during the last 15 years increasingly. Despite the creation of numerous additional dwellings in the past few years, there is still very low vacancy and a demand surplus in urban residential areas. The homeownership rate differs in Zurich (8.1 %) significantly from that of Switzerland (36.8 %) [10]. In Zurich nearly 30 % of all dwellings are owned by housing cooperatives. From this belong about 11 % to the city of Zurich or to urban foundations and other public owners and 18 % to housing cooperatives [17]. There is a total of approximately 150 housing cooperatives in Zurich.

The cooperatives exert themselves actively for affordable housing. This is illustrated by numerous innovative projects, one of which is the project "Hunziker Areal" of the cooperative “mehr als wohnen" that is used in this contribution as a case study. The housing politics of the city of Zurich builds strongly on the housing cooperatives and supports them in various ways.

The costs of renting a cooperative dwelling are around one third lower than a dwelling of private or institutional investors. The main reason for this is the cost of rent. As owners the city and the housing cooperatives must not generate extra returns. The rent is used for the ongoing maintenance upkeep and administrative expenses and for transfers to reserve for major renovations. It must cover all ongoing expenses, taking). The affordable rents motivate many interested parties to get a dwelling of a housing cooperative. But this is not the only reason, because the housing cooperatives in Zurich are considered at the same time to be one of the most innovative housing market actors.

3.3 Political support of housing cooperatives

Since the end of 2011 due to a national referendum a new housing-political principle article envisages in the municipal code of the city of Zurich, that the city government has to increase the share of non-profit dwellings by 2050 from 25 % to one third of the rental housing stock. This should be done mainly by the housing cooperatives and with the support of the city.

With the help of public funding schemes, non-profit housing developers get building land from the city at an annual, market-usual building law interest. Thus, the city benefits from the projects of the non-profit housing developers because in the long run it has lower social expenses. In order to enable low-income households the membership in a housing cooperative, there is also the possibility that the city of Zurich or another supporting institution covers the corresponding entry of capital for these households.

The city of Zurich also exerts itself about its endowments for the non-profit housing and acquires with public money corresponding properties or building new. The city has three foundations, each with its own purpose: *Foundation age living, Foundation for obtaining affordable housing and commercial rooms (PWG), Foundation for families with many children*. However, the demand for these specific target group dwellings is larger than the supply [20] [21] [22].

For the creation of additional living space in Zurich, the city has identified ten development areas. One of them is located in Leutschenbach on the border of the city, where the in the following described case study Hunziker Area is located.

4. Case study cooperative housing project Hunziker Area in Zurich

4.1 Objective

The case study Hunziker Area stands for a cooperative housing project with housing, working and living space for about 1,400 people. The cooperative “mehr als wohnen" pursues ambitious social, ecological and economic aims. It wants to show innovative solutions how under the present social conditions and requirements life can be organised solidary and jointly. This is also evident in the guidelines that the Executive Board in early 2013 adopted (see Fig. 1).

The cooperative loolks for new ways of process design and mixing strategies [6]. Therefore, the initiators call the project an "innovation lab for the non-profit house building" [24]. The city council supports the the cooperative’s project on the Hunziker Area. It correspondents with the city’s program “Living" which states: "The city of Zurich also remains an attractive residential city for all social classes and age groups in the current, demand-driven growth. (...) The city council exerts itself for the good social mixing of Zurich which makes an essential contribution to the social-political stability and a high quality of life" [25].

Basic principles of the housing cooperative "mehr als wohnen"

„**1. We are part of the cooperative movement and a lively city** and contribute to their development. To achieve our aims and to learn thereby, we are ready to take limited risks. With new building projects we develop our vision further.
2. Our guideline is the 2000-watt society. We expect an appropriate use of the buildings and a conscious consumption and mobility behavior and provide incentives to do so. As many basic needs of the residents as possible should be satisfied in the area with locally and sustainably produced products.
3. We create affordable housing by building economically, apply the rent costs and reinvest revenue surpluses. The rental income permits the maintenance of the properties, provisions as well as financial resources for the further development of the cooperative. Connected to the rent is a financial contribution to the promotion of solidarity, sustainability and culture.
4. We promote initiative and self-organization and provide rooms for common activities. Who lives or works with us, should and can exert himself as a cooperative member and in participatory processes for the aims of the cooperative.
5. We give space for the most different residential forms and life forms. The so originating social variety requires tolerance and openness of all partners. Our commercial sites allow living and working at the same place. They serve the residents and the quarter.
6. We offer services for residents, businessmen and guests. We create micro-jobs for residents and work together with social and non-profit organisations. We promote neighborly help and also create instruments to reduce personal emergency situations."

Fig. 1: Summary of "Baugenossenschaft mehr als wohnen" [23] (translated)

4.2 Emergence

In 2007 the 100th anniversary of the Zurich non-profit house building took place. At this time the housing cooperatives in Zurich played a key role as a counterforce to the increasing segregation because of no longer affordable housing. In 2007, they provided 34 % of the 2.247 new homes [26] and till then have been important market players for the creation of affordable housing. In addition, their aim is to prevent housing speculation. Peter Schmid, president of the newly founded cooperative "mehr als wohnen", emphasizes: "Always cooperatives have stood in contrast to the free market: A cooperative is a self-help organization, therefore, the residents and female residents are central to us and they are more important to us than the return. We take away living space from the speculation and supply the population with affordable housing" [27]. This representatively expresses the self-image of the cooperative.

Following, the cooperative "mehr als wohnen" launched a project of the same name. 35 existing housing cooperatives in Zurich have provided capital for its establishment. Through this solidarity they allow the cooperative to realize the new settlement on the 40,000 square meter Hunziker Area in the southern edge of the developing area of Leutschenbach to Schwamendingen in the northeast of the city. This has traditionally been a "work area with commercial use" and should now convert to a mixed quarter which is characterized by high-quality services and housing. Quality of open spaces (among other things Leutschenpark) and new district infrastructure (among other things a school) as well as measures for the improvement of the location qualities should contribute positively to the development of the area [28].

4.3 Project development

A large-scale architectural competition contributed to the aims in terms of sustainability, social mixing and affordable housing. Four architectural firms were selected as a result of this process, to build the quarter of the future. In addition these had to proceed in a dialogue phase, come to agreements and rework their draughts partly radically. The project includes 370 new dwellings with communal and public uses. There are common rooms, stores, workshops, a restaurant, a guest house and site-related infrastructure on the ground floors as well as a "reception" with service offerings which are partially based on neighborhood services. 100 jobs will be created there. Five house families with 13 large houses, a center and differentiated exterior spaces for different uses and claims have been planned [28]. The traditional values of housing cooperatives, such as security, family friendliness and affordable housing are complemented with a varied offer in the space program, to meet the different residential biographies of the residents (see below). Overall, the dwellings are comparatively inexpensive for Zurich relations. A 4-room flat is to obtain for less than CHF 2,000 (cold, including built-in kitchen). Other comparable flats in Zurich North cost between 2,500 and 4,000 Swiss francs.

Besides the affordable housing at the same time far-reaching environmental aims are implemented. Conscious consumer behaviour of the residents, low energy consumption, renewable energy and non-toxic, ecological building constructions are in main focus. On the roofs are photovoltaic systems, the houses fulfill the Minergie-P standard. Also projects for urban gardening and farming, e. g. as a school project and to the use in the midday care, are contributions to the environmental aims. Besides, the Hunziker Area is designed as a car restricted settlement. Who is reliant on a car - for example, because he works at night or must deliver goods professionally - has the possibility to make an application for one of the 106 parking spaces in the underground garage, otherwise the area remains free from parking space.

4.4 Mixed inhabitant's structure

The project aims at a social mixing of young and old, various household sizes, and income groups as well as nationalities. As an orientation frame the age and household structure as well as the proportion of migrants in the canton of Zurich is used. For example, there are many 40- to 50-year-old people, who are taken into account also in the Hunziker Area in sufficiently large numbers. Designated are diverse types of housing: for large families, age apartment-sharing, couples and individuals, families with one or more children and people with care needs. An important target is the group of the elderly. Since up to now the cooperative „ more than living“ receives most enquiries from people more than 60 years old, often from such who want to found an age apartment-sharing with friends. They are particularly interested in the so-called satellite homes. Here several parties live, who each have their own room with a toilet, shower and kitchenette. In addition, the apartments have a large common kitchen and other collectively used rooms. Besides the common living this type of housing offers favorable financial conditions because of the reduced living space per person. [24]

The segment of family dwellings (4.5 and 5.5 rooms) is also strongly represented; their proportion is over 40 %. Moreover, there are studios, greater flats for 8- and 9-residential communities [29]. The foundation Zuricher Children and Youth Homes sets up housing groups. 60 rooms are reserved for students. The foundation Züriwerk creates 40 partially or constantly supervised dwelling places for mentally handicapped people. Specific offers such as for disabled persons in need of care or elderly people, for temporary housing or guests and also extra rentable rooms, are also planned. [30]

20 % of the flats are subsidized according to the Swiss Housing Promotion Act of 2003 [31]. The building law contract with the town intends this. The guidelines for the award are strictly kept. Who earns more than 49,900 CHF (1 person) or 58,800 CHF (2 people and more) and has more than 200,000 CHF of taxable property, cannot be supported [19]. Other, about 5 % are rented to approved institutions that are active in the housing care for underprivileged. This is, for example, for the foundation Domicil the case which provides living room mainly for large migrant families with small budget. Migrants should also be considered in accordance of the proportion in the canton of Zurich for dwellings. This means that around 20 different nations will be represented. Besides, an internal solidarity fund enables temporary bridging financially difficult phases of life by a grant.

4.5 Process orientation

For the project Hunziker Area the process orientation has been an important principle for the common work from the beginning. It refers to the configuration of the project and already appeared in the competitive procedure, which was marked by dialogue among the winners and the cooperative. Through dialogue the desired qualities should always be reflected and sharpened in the awareness that the implementation could be forced in a joint effort.

In relation to the cooperative members this means that from the outset they had the possibility of leading the dialogue about the project in so-called "echo rooms". Here they discussed the state of the project, the upcoming work and miles stones, types of housing, ecological standards, sustainability, participation and volunteer work, etc. There is both an informal communication platform on the website of the cooperative “mehr als wohnen" with lots of information connected to the project and date announcements as well as even rather informal regulated quarter-groups, such as a meeting place or groups on sustainability and urban farming, among other things. These groups are allowed to request resources (rooms, materials, promotion among other things) from the housing cooperative and are available for all residents of Hunziker Area. Andreas Hofer, Project Manager of cooperative “mehr als wohnen", underlines this philosophy: "In the center of the interest stands the person, not the technocratic utopia" [28].

5. Results and conclusion: Sustainable and affordable housing for everybody?

To sum up, concerning the initial question, the case study Hunziker Area stands exemplary for a high demand of a comprehensive sustainability strategy. High standards for sustainable planning and building as well as an ambitious combination of environmental, social and economic objectives and requirements have been and are intended to be realized in the future. Ecological and energy-efficient building constructions, mixing, inclusion and affordable housing are not only guiding principles but were also strictly pursued in the course of the implementation and were lived continuously collectively with the residents. The simultaneous realization of different objectives appears feasible, although an evaluation of the initial questions is only possible after the completion of the project and after the stabilization of the residents. Besides, there is a number of other good examples of housing cooperatives in Zurich, both in new building or replacement building as well as in renovations, which are following this comprehensive approach.

As examples the inventory renovation Sihlsiedlung (General Cooperative Zurich), inventory renewal Hegianwandweg (Family-Home-Cooperative), settlement Hardturm (construction and housing cooperative KraftWerk1), Kalkbreite area (cooperative Kalkbreite) can be named [19] [6]).

To implement the ambitious objectives in the Hunziker Area a mix of different strategies and instruments was used. From sides of the housing cooperative as well as with the town, it is not sufficient to merely act with single instruments. Rather it is the combination of instruments, which need to be coordinated even over the responsibilities of the various groups of actors such as the housing and the public sector that contributes to successful project development.

Housing cooperatives can contribute on the basis of their particular legal form by qualitative objectives and the use of appropriate formal and informal instruments to an integrative, on mixing and sustainability aiming urban development, in order to provide affordable housing and to include socially underprivileged parts of the population. Used strategies and instruments are among other things mixed allocation politics (among other things on the basis of a database), dialogue orientation, resident participation from the idea up to the implementation, economic building as well as the use of the cost rent and the reinvestment of the revenue surpluses. Thus, the rent income permits the maintenance of the properties, provisions as well as the financial resources for the further development of the cooperative. In addition, with the rent a financial contribution to supporting solidarity, sustainability and culture is covered. [30]

The tight housing market in Zurich and the corresponding need for action on the part of home demand and subsequently for the politics are certainly supportive for such innovative housing models. "Due to the low costs of renting the non-profit housing developers look cost dampening and enable households with low and middle incomes in first place only to be able to stay in the city" [32]. The cooperatives contribute significantly to the goal that social diversity should possible in the city. In addition, the housing project shows that cooperative housing is the clever fusion of individuality and community, which has to grow already in the origin phase of the project. Besides, the community also encloses the quarter, and links the various actors and complements in the sense of an integrated neighborhood.

At the same time it has become clear, that without urban default with regard to the rise of number of the non-profit dwellings in Zurich as well as the subsidization of 20 % of the dwellings according to the Swiss Housing Act only a clearly lower number of dwellings for low-income households would have been provided. Although the price level of the dwellings lies all together clearly below the rest of the Zurich housing market, both the ideally and the real promotion of affordable housing are the main drivers for the implementation of the key objective "creation of affordable housing." The momentum of the cooperative housing development would not necessarily lead to the fact that this goal comes to the fore. This becomes clear in various statistics of Zurich about the limited housing space, that indicate that cooperatives in average cover the lower and middle class, but rarely the low-income parts of the population as a target group.

Furthermore, the affordable housing, according to the project managers at the Hunziker Area, also draws lower-income people who partially have never been interested in cooperative housing, sustainability or car-free life. Besides, the integration of low-income households, among other things migrants and educational-distant parts of the population, remains also for the cooperative project a challenge. Socially underprivileged groups are not excluded, but in view of the cooperative “mehr als wohnen” [30] it needs more strategies and methods to integrate them actively. Nevertheless, in daily practise rather the informed and active people show permanently interest and become a member of the cooperative. Therefore, the cooperative “mehr als wohnen” [30] sees as an important precondition for good cooperation that in the new settlement already before moving into the dwellings, structures and conditions for a comprehensive sustainability and civic engagement are created. They should orientate on the interests and abilities of the residents and help to strengthen long-term identification. In Hunziker Area, through cooperation with, for example, the foundation Züriwerk that cares in particular about the integration of disabled people and the participation in the new residential area the cooperation of all social groups can be supported. According to the cooperative "mehr als wohnen" the Hunziker Area in the long-term will be a quarter where one third of all residents assigned rather to the financially underprivileged households.

From a comparative point of view the Swiss case study points out that between Switzerland and Germany, just as other countries, a number of differences exist, which complicate the transferability of the experience. These relate to legal, political and economic conditions as well as cultural specific features. Accordingly, it would be worthwhile to work on deepening questions within the scope of further research in this field to better understand the specifics, but also the limits of transferability.

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Creating Awareness for Sustainable Construction through Practice-Oriented Teaching in Architectural Education in Eastern Africa

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Summary

Both the impact of the building sector on climate change and the impact of changing climates on the environment and subsistence of growing populations are especially precarious in developing countries. Rapid population growth rates and the rapid urbanisation of cities lead to enormous consumption of imported, industrially manufactured building materials. Nevertheless, the integration of sustainability of building materials and constructions into architectural education remains theoretical, a holistic approach to concepts of energy and resource efficiency in design studio courses is rare. In many countries, there is still a lack of locally trained experts who can link state of the art knowledge to regional building traditions.

With a focus on East African countries, the University cooperation project JENGA (funded by EU/ACP in the programme Edulink) described in this paper, aims at improving knowledge of and application of sustainable, low energy building materials, which are often wrongly associated with backwardness and lack of resources, through practical oriented, project based courses at East African Schools of Architecture. Prototypes designed and built by students from Universities in Kenya, Rwanda and Uganda will be used to illustrate challenges and potentials of sustainable construction materials and explain how the image of building materials can be improved by linking them to professional interest through good architectural design.

Keywords: practical education, problem-based learning, sustainable building, East Africa, capacity building

1. Introduction

The University cooperation project JENGA (Joint Development of Courses for Energy-Efficient Sustainable Housing in Eastern Africa) aims at academic capacity building and knowledge transfer for architectural education at three East African Universities. All three institutions hope to add a new way of studio teaching to their existing course curricula by introducing problem-oriented learning based on practical examples, model and prototype building and team work in studio.

Similar to many places in the Global South, in all four African countries concerned /Kenya, Uganda, Rwanda, South Africa), supply and generation capacity for electricity cannot keep pace with the growing demand for energy for households and production processes. A tremendous inefficiency in the use of energy, particularly in the domestic sector, coincides with rising energy-prices, a tendency which has led to energy becoming the limiting factor economic growth in the recent years. At the same time, the rapid increase of the building sector offers an opportunity to implement innovative solutions to challenges faced by African countries, which have shown an amazing ability to leapfrog slow or ineffective development steps in other fields. Within the building sector, the potential for saving energy and resources in the future lies both in the production of materials and in the construction and operation of buildings. The efficient use of energy within built structures and the choice of construction materials with a low carbon footprint play a major role in reducing the ecological footprint of a society.

However, while energy efficiency in buildings and the relevance of life cycle impact of construction is a topic well documented, these issues are hardly put into practice in developing countries: this is due to a lack of practical training of teachers and practitioners in new technologies, an insufficient dissemination of the international knowledge-base at institutions of higher education and an unsatisfactory reflection of this knowledge base in existing curricula. The most critical aspect, however, is a lack of practical applicability and adaptation of theoretical knowledge to a local context. This is where JENGA aims at first steps of improvement at the partner institutions. Developing the housing sector is a major issue in all three East African partner countries, as well as in South Africa. The choice of design studio assignments within JENGA therefore focuses on residential and similar small to medium scale buildings.

The experimental course content during the three-year project period includes workshops, field excursions and regular visits by guest critics from partner institutions, with the goal of initiating the implementation of practice oriented design-build courses at each participating HEI in Kenya, Uganda and Rwanda. As the evaluation of the first part of this process will show, all the above-mentioned aspects of the programme have proven to be quite challenging to implement.

Re-shaping course content and studio concepts have been complemented by an on-going evaluation of facilities available for practical teaching – like materials labs, workshop areas or laboratories for measuring and simulation equipment. It is intended to identify and mitigate prevailing barriers to their regular use, with a final objective of implementing courses primarily based on practical equipment.

2. Situation and Objectives

2.1 Building Construction in Sub-Sahara Africa

Architecture and construction are key fields to establish sustainable urban and rural dwellings for growing populations. In order to raise socio-economic, educational and health standards on the African continent, construction needs to break away both from inefficient technologies and from inadequate foreign strategies, including the dependence on expensive imported resources like cement or steel. Instead, adapted technologies, affordable construction and environment-friendly materials have to be further developed and implemented. Furthermore, waste of energy for heating and cooling energy can be avoided through intelligent building techniques.

It will be crucial for schools of architecture to impart these issues to their students to adequately prepare them for the challenges of their professional careers an create a demand for changing policies among professionals. Concentrating on the design and build of full-scale prototypes in various contexts, the programme attempts at informing junior teaching staff and students on how to link theoretical knowledge to realistic design tasks.

2.2 Architectural Education in Sub-Sahara Africa

Practice-oriented education at higher education level for architects and engineers in Africa is currently not the rule. Practice orientation improves students' understanding of complex design processes, as well as their practical skills, creativity and problem-solving abilities. Training of young professional in these same skills will help to create the urgently needed local teaching staff.

The cooperation described in this paper aims at strengthening the practical orientation and interdisciplinary approach within architectural education. By creating a network of partner universities in East Africa and supporting it with expertise from Germany and South Africa, the goal is to develop curricula, which reflect the fast growing pace of countries in the global South. The proposal therefore offers a unique framework for strengthening existing competencies as well as building new capacities, creating an exchange and dissemination model with benefits for all sides:

- Cooperation with and among East African universities will create win-win partnerships, strengthening teaching and knowledge management competencies including student centred teaching methods
- African universities can build on project partnerships in order to increase their teaching capacities, especially by increasing the number of well trained local academics
- The German partner will come to a better understanding of the African context local building and construction practices adapted to the climatic conditions ("vernacular knowledge") including methodologies, intercultural competencies and an academic network.

Fig. 1 practical exposure: student excursion to a local brick making cooperative in Rwanda

3. Methodology of the Project Cooperation JENGA

3.1 Design-Build as a Teaching Method

Research by design and through practice is a well-established model in architectural education. The iterative process of designing buildings has been described as the “circularity between drawing and making and then back again" by architect Renzo Piano, explaining his own working procedure [1]. In a similar way Richard Sennett draws our attention to the importance of the practical aspect of work for design and creativity in his book "The Craftsman" [2]. A major part of the architectural process depends on balancing internal and external constraints in a design solution – a highly complex procedure, in which problem definition and problem solving are equally important. A circular process of thinking and making, drawing and building, leads to professional experience based on and informed by personal judgement.

Within architectural education and practice the importance of craftsmanship and of a hands-on approach is not new. Examples of architectural learning-by-doing, which link education with technological experimentation, but also with social issues of modern society, are not new. These aims were already of primary importance at the Bauhaus, founded 1919 in Weimar, Germany. Here workshops were placed at the centre of a progressive curriculum that aimed to fuse craft and design education with avant-garde artistic practice. This tradition later emigrated with some of its initiators to the United States, where currently almost thirty schools offer such programmes [3]. One of the most famous of these, Rural Studio at Alabama's Auburn University [4], established in 1992 by Samuel Mockbee, explicitly aim to explore "how architectural practice might be challenged with a deeper democratic purpose of inclusion" [5].

The East African situation offers ideal conditions to test this. Architectural prototypes are physically built realisations to test and explore a system with clearly defined but unresolved questions, demonstrating the complexity of a full-scale project. The central element of JENGA, both in terms of schedule, and also in terms of tangible results, is to create a sequence of design and construction courses which lead up to the construction of small, but full-scale prototypes by the student group. In order to improve practical orientation of design and construction classes, these prototype buildings can be used to explore and experiment with building typologies, experimental constructions and new technologies. Particularly in the context of developing countries, showing the "example", the "prototypical model" has proven the most effective way to influence a visual and professional culture.

3.2 The Three-Year Programme of JENGA

JENGA addresses the course programme for second and third year students of architecture, with the aim of an established procedure at the end of the funding period for realistic design tasks, student group work and practical exercises in design and construction studio class.
The core of the programme will be to run a practical building workshop at the end of each academic year.

This theoretical programme is based on input from experts in different fields of architecture and engineering, including social and environmental parameters, materials science and structural behaviour, which is provided by academics from the African and European partner institutions during the funded cooperation. Regular reflective evaluation and planning workshops ensure that the results achieved each project year are made available for subsequent project phases, thereby adding to and improving the courses given the following year and building up progressive knowledge base and a long-term institutional learning process.

Throughout the period of three years, the external input in the activities started at a high level and has been reduced gradually, requiring a progressive increase in responsibility and capacity of local staff, who is intended to eventually take over the lead in the programme. Thus the activities are focussed both on course content and teaching methods and on capacity building for teachers, especially for junior staff and young academics, with the objective of improving their qualification and teaching experience. The intended result is a course programme without external input at each HEI, however supported by institutional networking and personal collaboration, forming the basic framework of continuous exchange.

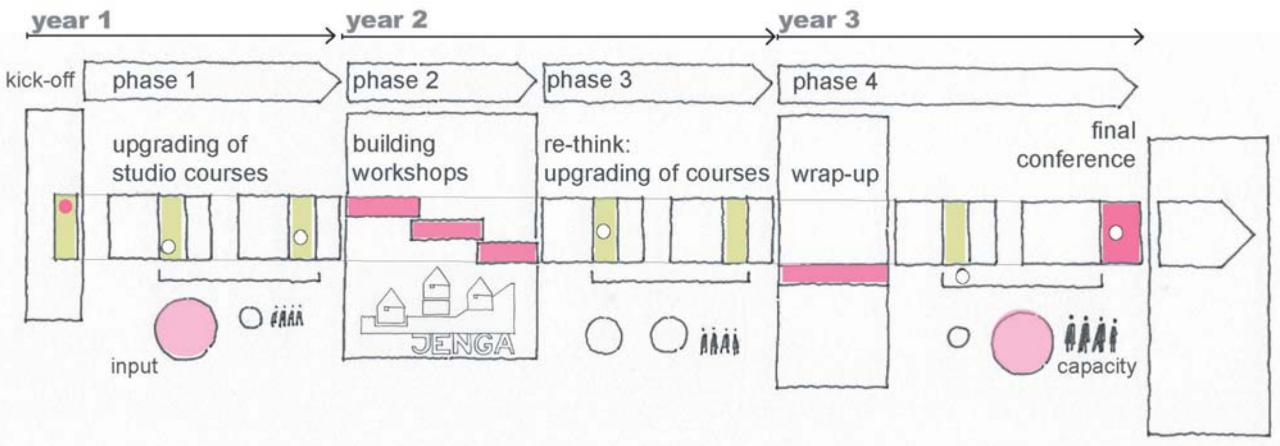

Fig. 2 JENGA activity matrix, showing level of external input

The project also sets out to contribute to a scientific knowledge base on how architects can contribute to resilience of the built environment and strengthen local solutions to global environmental challenges. This will assist the process of making architects part of a resourcing network for more sustainable development in countries of the Global South.

4. JENGA Project Activities

4.1 Design and Construction Courses

During the first cycle of design and construction courses, each participating school of architecture developed a design studio based on the general objectives of the programme: small to medium sale construction (housing or small public buildings), low-tech construction suitable for experimentation with alternative building materials and a real background for the brief, offering clients' needs and expectations, a real site with topographic and climatic features. According to the size of classes, and course schedules different activities like field excursions and workshops were incorporated, where staff and/or students from partner institutions came in to participate or contribute.

4.1.1 Studio Project at Jomo Kenyatta University of Agriculture and Technology (JKUAT)

Students at JKUAT were given the opportunity to work on the design of a real client's project for a new primary school in Dodoma, a socially fragile area of Nairobi, Kenya. The client's input was used as a declaration of intend for a comprehensive school with a large number of facilities, leading to a brief for a master plan on the designated, currently undeveloped site. Students were taken to a site analysis visit to document specialities of the urban situation, topography, infrastructure and living conditions of the future users. Partners from the JENGA group participated in a mid-term studio presentation and gave input both to the student group and to the studio teaching team. Potentials for a subsequent construction course, building on the design results were discussed.

The results of the design semester were taken up again in the following term to be the basis for the studio course for the second half of the 3rd year at JKUAT, which is dedicated to timber construction in the existing curriculum. This limitation in the variety of construction materials determined a focus of the course on wide span construction, which were opened up to a number of choices for timber-based construction materials by the studio teaching team, including timber logs, industrially processed glue-laminated timber and bamboo. The evaluation of the environmental impact of timber used as a construction material was part of the assignment.

The construction studio class started with a new design phase for a multi-purpose facility as a basis for the subsequently planned design-build project, to be realised on a site on campus close to the studio building. This change of place and use led to an entirely new design. Challenges of this strategy will be discussed further on in this paper.

Students of the project class had the opportunity to re-visit a design-build site near Nairobi, which had been completed some months earlier together with participants from JKUAT during their studio class, again under the guidance of their studio teachers and external guests from the JENGA group.

Fig. 3 JENGA design-build construction site at JKUAT, Nairobi

The final results of this construction studio included a number of construction models for timber framework, joints and trusses. In preparation for a live project with students constructing a prototype workshop and exhibition space, the student group supported by supervising lecturers revised and specified the studio results to be construction drawings. The actual construction project was started in August 2015 (Fig.3) but not yet completed at the time of this publication.

4.1.2 Studio Project at the University of Rwanda, College of Science and Technology (UR-CST)

The design brief for UR students was based on low-cost housing for both the design and the construction semester. The design brief asked students to come up with solutions for mixed-income housing prototypes on a site in Kigali. Students were asked to study precedents for sustainable

housing types and identify ways how to improve housing design for their local context in Rwanda, with a focus on topography for the JENGA-theme ‘slope’ for Kigali.
The studio course was supported by a number of excursions to learn more about alternative masonry blocks and their properties and environmental impact, including a hands-on workshop at a local brick making cooperative. Colleagues from the American University Cairo taught a workshop on climate related design and simulation.

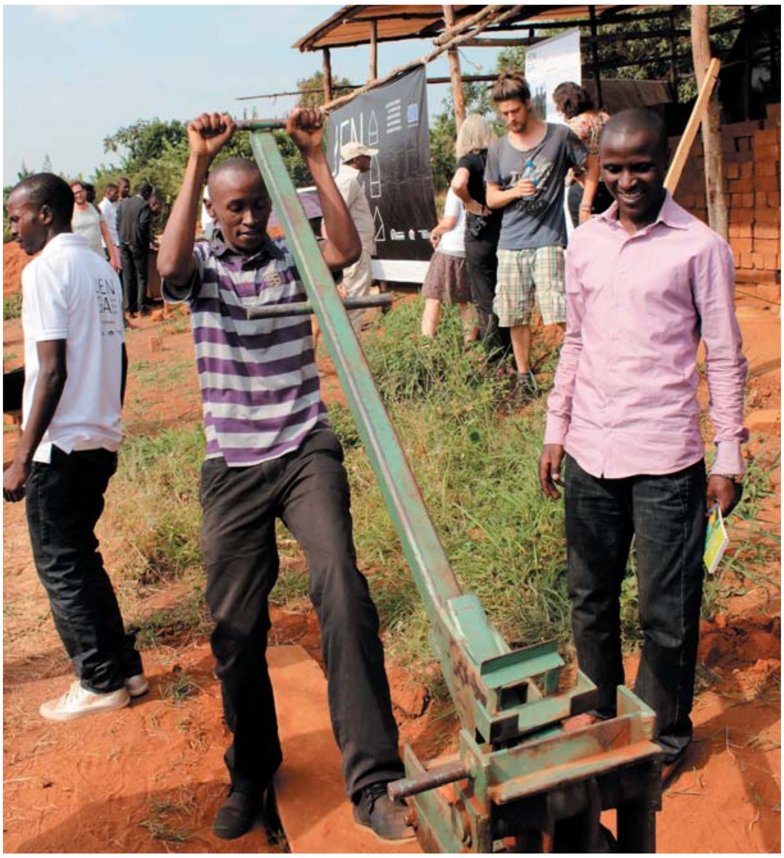

Fig. 4 Stabilised brick making at the UR design-build construction site in Rwinkwavu

The second semester construction course had to be limited to a few seminar days due to a lack of teaching staff for construction technology. However, students were involved in a real building project for rural housing in Rwinkwavu, a village in the East of Rwanda. Stud worked on design solutions for prototype houses and supported the construction team with the detailing of the buildings prior to joining the construction site for their design-build experience. From July to September 2015, the student group worked on the construction site for the client Rwanda Village Enterprises (RVE) at Rwinkwavu, laying foundations and making compressed masonry bricks (Fig. 4). The buildings will be completed later in 2015.

4.1.3 Studio Project at Uganda Martyr’s University (UMU)

Students at the Faculty of the Built Environment (Fobe) at UMU were asked to deal with a challenging design brief for their design studio assignment: on a choice of two sites, a mixed use housing development including street infrastructure, public green spaces and a child car facility had to be incorporated into a master plan. One of the sites included existing but disused structures, which had to be included in the proposal. On both sites issues of high ground water tables or flooding during the rainy season had to be taken into account, reflecting the JENGA-theme 'flood' for Kampala. Students had to work in groups of 5 – 7 for this assignment, which proved an unusual and challenging framework for studio class.

Results of this first studio turned out to be complex and finally too sophisticated to be taken further for a real construction workshop. Instead, the course instructors decided to start a new assignment for a small multi-purpose exhibition space designed for a choice of three potential sites on UMU campus. In parallel, a group of students worked on technical input for the construction site in a building technology class. Participants of the construction classes had previously been involved in an experimental poured earth workshop, testing different material mixes and constructing sample walls with a poured earth technique (Fig.5).

Construction of the prototype started late in August 2015, the final outcome of the building workshop was not available at the time of this paper.

Fig. 5 Sample cube testing for poured earth prototypes by students from UMU, Uganda

5. Discussion and Evaluation of Achievements and Challenges

5.1 Achievement of Project Objectives

The process has lead to diverse results at the different institutions, as well as to some common challenges: At UMU and UR, a shortage of lectures in general and specifically for construction technology courses has existed for some time. The situation is a result of administrative challenges in hiring staff, a general lack of well-trained teaching staff and – especially in the case of UMU – in a remote location of limited interest to expatriate academics. Financial and professional incentives to work for a University are not sufficient to attract personnel for the existing vacancies; frequent administrative restructuring increases these difficulties. At JKUAT, the necessary high degree of cooperation between studio staff and lecturers needed to link theoretical classes to design studio, has proven to be an unfamiliar and somewhat challenging concept, as many members of staff are on part time contracts and not available for close coordination outside of teaching hours. All three institutions have to meet the expectations of external examiners, which is a further important limiting factor to experimentation within existing courses.

These reasons, as well as administrative challenges in securing sites, funds or even appropriate periods of construction time for the design-build projects, led to considerable delays in the project schedule. In the end, a sequence of construction projects with visits by partner institutions to each other's sites could not be realised. The construction projects were far from being finished at the end of the scheduled construction time, and involvement of students and staff from the original studio classes cannot be guaranteed.

5.2 Lessons Learned during the Project

At all three institutions both staff and students faced similar challenges in regard to teaching concepts and implementation of the design-build projects:

- Large size of classes makes individual and flexible teaching concepts difficult;
- The complexity required for a studio year design brief, according to existing, pre-defined course requirements, is not suitable for construction detailing and practical execution by the students; here, it would be necessary to redefine course requirements or add practical applicability as a desired outcome.
- The concept of group work is not well established in the current educational context in East Africa: individual work is valued more than group results; group work was therefore sometimes misunderstood as being done in a thematic rather than a cooperative groups during the first JENGA cycle.
- Intensive studio work is necessary to produce design results which can actually be built: this requires a high amount of well coordinated input from supervisors, which cannot always be provided for large classes or by part-time staff;
- A selection process to generate a real building plan for the practical execution out of a large number of individual solutions can be difficult and stressful for both students and instructors;
- It has been difficult to relate a studio design task to a site for actual realisation, especially when sites had to be identified on campus: the assignment needed to be somewhat unspecific to be acceptable as a multifunctional structure on University grounds. The most successful concept has been to join a construction site away from campus, as students from UR did in Rwinkwavu, which in turn is a logistic experiment difficult to repeat systematically and consistently once each year.

6. Conclusion and Way Forward

Design-Build projects are a very interesting and challenging form of problem-oriented learning and a suitable – although very special – alternative teaching method for creative and technical subjects of study. They have become increasingly popular at European and American Schools of Architecture, where they offer a way to expose student both to a very immediate and artisanal approach to design and to unfamiliar social or cultural contexts. The approach has been discussed, praised and criticised elsewhere [6]. The results, both in physical construction and personality development, have been highly accredited.

JENGA set out to explore the possibility to implement this kind of experimental approach into architectural education at three partner institutions in East Africa. The potential benefits are undisputed between those involved in the projects, even though the realisation has uncovered a number of challenges. It can be concluded that there should be two strategies to increase the significance of practical teaching in the context described above: One is to adjust the type, scope and investment of time and resources to the possibilities of faculties at the respective Universities. Smaller projects, design-construction partnerships with local NGOs or even the integration of external experiences from attachments could be first steps towards relating theoretical studio work to responsible professional involvement. This approach could already be shown to extremely successful in the building technology workshops for material testing and prototyping at UMU.

The second, more intermediate-term strategy will be to discuss existing frameworks including course requirements, assessment criteria so external examinations or job profiles for graduates. If a less academic, more practical and locally relevant perception of architectural education seems desirable, design-build can become an accepted form of studio class. The cooperation partners in JENGA will discuss and evaluate the results of their project work and try to define appropriate ways to implement practical exercises at each institution during the final project phase. The results of the cooperation will be published at the final conference in August 2016.

7. Acknowledgements

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Decision Support Environment – assisting the transformation of built environment towards sustainability

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Summary

This contribution highlights the need for transformation of built environment in European cities and explores the potentials of new, innovative methods and instruments capable to support these processes. The core discussion unfolds around the experience collected during the TRANSFORM project in the framework of which a new instrument – Decision Support Environment (DSE) - was developed. The paper shares the insights gained during this collaborative experience as well as provides a detailed description of the potential steps in urban-energy planning which could benefit from DSE application.

Keywords: Sustainability, built environment, transformation, instruments

1. Introduction

Even if information, models and implementation could be perfect in every way, how far can they guide us, if we know what direction we want to move away from, but not what direction we want to go toward? [1]

We have entered “the age of homo-urbanus” [2]. The national and international debates focusing on the alternative development paths for humanity are omnipresent and ‘THE URBAN’ has moved, like never before, into the forefront of these discussions. Weather concerning the Climate Actions, Smart City Developments, Sustainability Measures, Resilience etc. the prevailing tone in all of the themes is charged with the necessity for change and transformation.
While cities have always been the creative frontrunners in providing space for diversity and innovation as well as making the best of seemingly contrasting ideas [3], the voices for a more radical transformation are getting stronger and stronger. Wheather taking the economic, social or ecological perspectives, it is clear that going about in a business as usual manner is not an option any longer.

Looking at the European scale of development, the challenges we are facing are multifaceted and penetrate all dimensions. One of the most elaborate studies concerning the European urban future was published by the Office for Regional Policy, European Union, in October 2011. This document compiles investigations undertaken by more than fifty European institutions from different EU countries; it clearly highlights the challenges in front of us [4]. The study exposes some key areas, which need to be addressed, including physical, social, economic, cultural and environmental realities of our cities, if we want to ensure a sustainable future and to maintain as well as advance European model of urbanity and democracy. In this context, cities play a leading role.

While the 20-20-20 Climate goals have been widely accepted as a collective aim on the European level, there is a lack of a clear vision regarding the means how to achieve it. This may be due to the existing hierarchical differentiation between cities, ingrained in very differen local framework conditions and uneven starting circumstances where the motivation for achievement of these starts. Thus, the potential for transformation varies, depending on the local logic, within which urban areas are rooted. Furthermore, the economic and ecological dynamics of our cities are highly interwoven with global movement of people, goods and information: 'the administrative boundaries of cities no longer fully reflect the physical, social, economic, cultural or environemnetal reality of urban development' [4]. So, cities today are in a stretch between the inside-out and outside-in requirements, driving and shaping them.

Despite the varied circumstances in which cities are embedded, there is one outstanding commonality that is characteristic to all urban areas in Europe as well as globally. This general challenge that all cities are facing is the fact that urban ecosystems are increasingly under pressure: our current sprawling patterns of land use, exploitation of natural ressouces, depletion of existing biodiversity and ever growing 'hunger' for energy can not be sustained in long term. In order to counteract the existing behaviour of urban systems, to sustain and improve quality of life, while preserving natural ressources, we have to get not only innovative but also creative in terms of our approaches, perspectives, methods, models and instruments, which we can deploy effectively and cooperatively. Most outstanding however, is the need for a change of mindsets and attitudes shaping our problem-solving approaches; as Albert Einstein pointed out already in his time: 'We can't solve problems by using the same kind of thinking we used when we created them'.
It is essential to consider this background, while approaching the transformation of the built environment. Particularly Europe - most urbanized continent in the world [4] – contains mostly existing built fabric, which embodys the values, social processes and history of our society - 'cast in stone'. The spaces of cities are at the same time not a 'finished product'; these continue to undergo modifications while serving the society as catalysts for change. Some questions immediatelly arise in this context: how can we change and adapt existing built environment in a way that accommodates the dynamic social, cultural, ästhetic and economic requirements of today, while at the same time reducing the environmental footprint and energy consumption? Which stakeholders, information, instruments and methods do we need in order to effectively approach this task? Can we make the transition to solving these multi-dimentional challenges in an integrated and open, rather then isolated and fragmented manner? What impact has the rapid digitalisation in this context and what roles can it play? How can such decisions, which will have impact for the next century/ies be made wiser?

All of these questions were addressed in the European FP7 Project - TRANSFORM [5], which started in the year 2013 and was completed in late spring 2015. Six European cities: Copenhagen, Genova, Hamburg, Lyon and Vienna have worked together with utility companies, consultants and knowledge partners, each bringing their specific experience and know-how in a joint effort to find answers to the multi-dimentional questions of urban transformation.

The consortium of TRANSFORM poject pursued three core aims: 1) development of a Generic Transformation Agenda and more specific Transformation Agendas for each of the six project-cities; 2) development of a prototype Decision Support Environment (DSE) and 3) elaboration of tangible Implementation Plans for the Smart Urban Labs (SUL) in Amsterdam, Copenhagen, Genova, Hamburg, Lyon and Vienna.

Within given project program, the expert teams of Austrian Institute of Technology (AIT) and Accenture were entrustet with the task of DSE development - a prototype webbased platform - capable to process and visualise complex information as required by the stakeholders of cities. The European 20 – 20 – 20 climate and energy goals were taken as guiding targets for the development of the Transformation Agendas and as key indicators for the main parameters of the DSE.

2. Methodology

Developing the methodology and tooling to support decision making within the context of cities' energy transformation requires first of all an understanding of which decisions need to be made by which stakeholders, based on which information, for what purpose, and for achieving which outcomes. Getting to this understanding within the TRANSFORM program, started by identifying key stakeholders from partnering cities and helping them to formulate their decision support needs in the specific context of each city. The DSE development team used a variety of methods in order to distill the required information. The applied methods include in-take workshops, interviews, consultations with diverse urban stakeholders, such as utility companies, urban and energy planners, building owners, etc. Different layers of required information could also be extracted during highly interactive Intensive Lab Sessions, which took place in each of the six TRANSFORM cities and exposed specific, most urgent themes and topics to be addressed in the development of DSE. This interdisziplinary collaboration resulted in a joint definition of requirements that Decision Support Environment had to fullfill. At the same time, working directly with a great variety of stakeholders has exposed existing gaps and sensitive topics, such as data fragmentation and availability as well as often challenging cross-sectorial exchange of information and communication, to mention but a few.

In addition to the list of functional requirements (recorded and explained below), this process resulted in an understanding that the overarching requirement for the TRANSFORM Decision Support Environment is the ability to support city stakeholders in the process of translation of city data into usable information, through the translation of this information into insights and finally to the translation of these insighst into concrete actions. In other words, the TRANSFORM DSE should support informed decision making by enabling the use of available data sets to generate information and insights needed for energy planning and definition and evaluation of alternative-low carbon measuers and scenarios.

Cities are by nature complex environmental, economic and social systems and cannot be easily and accurately described and analyzed from the top-down perspective [6]. Taking this perspective often assumes equal geo-spatial and energy related conditions across the city as a whole and omits local constraints and opportunities. This is the main reason why cities are advised to move beyond the top-down and one-size-fits-all approach to transforming themselves into low-carbon cities. The experience in TRANSORM project shows that basing the decisions on more detailed bottom-up analysis - using location specific and granular geo-spatial energy data - provides new understanding of different correlations within built environment and serves as basis for innovative approaches to development and transformation . In a close collaboration between the core DSE development team and the interdisciplinary consortium of the project, a number of concrete requirements conserning the structure and functionalities of the DSE were defined. Following are brief explanations on each of the key requirements:

Use of open and granular data – One of the first decision support environment requirements was the need to work with the open city data at the granular geo-spatial level, providing valuable insights about the current energy use and related emissions, but even more about the opportunities to make a significant impact in the future. This also enables more informed and fact-based discussion between city stakeholders and allows for much more effective analysis and a far more accurate estimate of the potential impacts interventions might have on the urban energy system. This in turn can increase the speed and quality of energy transition related decision making and enable continuous process of translating these decisions into specific interventions.

Visualization and context analysis – Another one of the initial DSE requirements named by stakeholders was the ability to enable visualization and analysis of finely grained geo-specific city data. This was including detailed energy consumption as well as energy potential at all levels in the city, with the aim of identifying opportunities for achieving energy, emission, and sustainability targets of the city. Using cloud technologies, the DSE should allow access to massive datasets and enable users to viasualise and analyse this data from any angle they desire.

Definition of targets and scenarios – third core requirement was the capability to enable users to set specific energy and emissions related performance targets. In addition, the DSE had to allow for definition of a series of possible future scenarios on energy and city development which could impact the timing and effectiveness of measures aimed at reaching previously set targets.

Definition and allocation of measures – DES also had to enable flexible and highly detailed definition, combination, and selection of a whole variety of energy and emissions related measures aimed at helping the city reach its energy and climate targets. In addition to this it had to enable geo-specific and building property specific allocation of these measures in time.

Simulation of future scenarios – An important requirement was to allow users to define and run different simulation experiments under a number of future scenarios and thus enable prediction and visualization of both short-term and long-term impacts of various combinations of measures on selected energy and emissions performance indicators. The simulation would need to be based on the discreet event modelling methodology, enabling simulation of changes and interdependencies between all the variables in time.

Performing analysis of costs and benefits – One key element of the purpose behind the DSE is to enable translation of insight into concrete actions. To enable this, the DSE had to provide for the cost-benefit analysis of different portfolios of related measures and to help identify the most optimal combinations of measures as well as where and when they would need to be implemented.

Ensuring flexibility and ease of use – From the perspective users the DSE had to deliver user-defined level of granularity of visualising and analysing information. In addition, it had to provide an easy-to-use interface for defining an almost endless variety of scenarios, measures, and simulation experiments, as well as to enable the users to almost intuitively go through the required iterative steps when using the DSE. The stakeholders, applying the DSE in their context, need to be in control by defining which levers they want to manipulate and which results they want to view.

Provididng broad applicability – Another user focused requirement was the need for the DSE to be beneficial to multiple city stakeholders including municipality, housing corporations, and/or network utilities. The DSE has to continuously serve a variety of purposes, like energy transition planning, urban renewal, and/or new city development planning.

Accessibility and open-data support – The last functional requirement was the need for the DSE to be accessible online and serve as an online platform. The city data and information should be stored and can be added online on a continuous basis. The DSE should allow for an easy management of data set access levels, varying from fully accessible to completely secured.

3. Results

3.1 Making information behind complex urban interrelations visible and accessible

In line with the other outcomes elaborated during TRANSFORM project [6], a Prototype Decision Support Environment has been completed and now can serve diverse urban stakeholders in development, negotiation and decision making processs by providing valuable and open information. It supports the integration between urban and energy planning processes and provides detailed insights in energy related performance of urban districts, cities or even metropolitan regions (depending on data availability and provision).

Concrete steps are to be undertaken, if relevant stakeholders are to extract the full benefits from DSE applications. Before working with the Decision Support Environment, the users need to first gather city-specific geospatial and energy-related data on a granular level from different data owners (e.g. energy suppliers, municipality, network companies). Before it can be used, the data needs to be cleaned up, often combined, and aggregated, if necessary to avoid privacy related issues. In addition, the energy consumption data needs to be enriched using statistical analysis to reflect specific energy consumption purpose. Once data is fully translated, it can be uploaded into the TRANSFORM database. Some of the most common data used is: electricity consumption, gas consumption, heat/cold consumption, a number of functional and energy related building properties, solar potential, wind potential, and aquifer thermal storage potential.

Data upload is followed by the context analysis phase of working with the DSE. Users can first view and analyse different energy and climate KPIs from the city (e.g. natural gas consumption, CO_2 emissions, or energy costs). This and other data layers are accesible through easy to zoom in or out maps or charts.

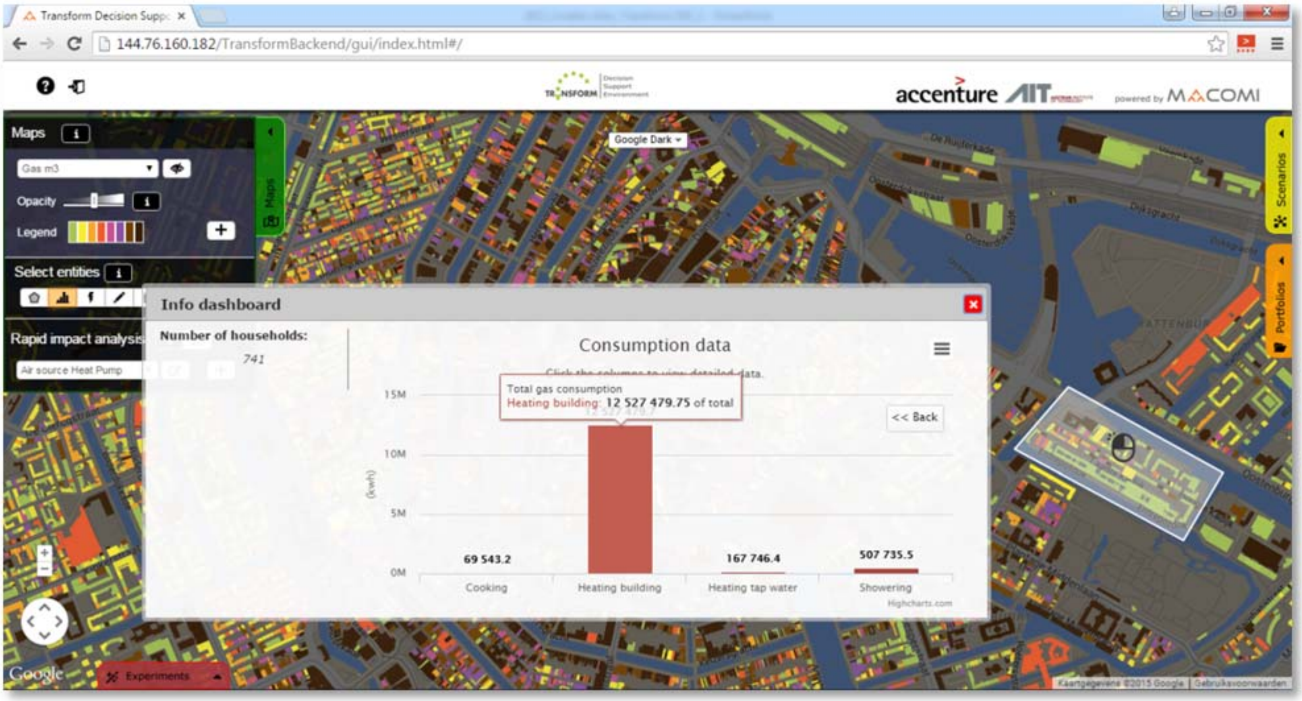

Fig. 1 Information on status quo of energy consumption within a defined area

The DSE also enables running of data queries on different spatial levels (buildings, blocks, districts) and across different energy and climate related indicators. This is helping users to identify potential opportunities for reducing energy consumption or benefiting from integration of renewable energy. In addition to analysing the data, the DSE provides the functionality of setting city specific energy and climate performance targets against which the impact of proposed portfolios of measures can be assessed.

3.2 Modelling of measures and alternative scenarios

An important functionality of the DSE is the ability to set scenarios for a number of variables that are outside of the direct control of a city and will be used to enable sensitivity analysis (e.g. energy prices, temperature patterns, population growth, or disposable income growth). For each variable users can define changes in value through time and create a number of different scenarios for each of the values (e.g. growing or stabilizing gas price) or load existing scenarios (e.g. country averages). These scenarios can be used to test how robust the proposed solutions are, considering the uncertainty of future developments.

Following the scenarios definition users' first need to apply the KPI definition editor in order to define, construct, and edit the algorithm logic behind the Key Performance Indicators (e.g. carbon emissions, or energy costs). Following the definition of KPIs, the stakeholders can work with the measure editor to define, construct, and edit the algorithm logic behind different measures aimed at helping the city reach its energy and climate targets (e.g. thermal grid extension, installation of heat exchangers, or placing of façade solar panels). Both, the KPI editor and measure editor, enable urban actors to define the necessary models using an interactive mind-map like model building environment, which does not require any programming skills. This makes all models behind measures and KPIs easy to construct, transparent, and always open to changes and improvements. Once constructed, measures can be stored in the measure library for later applications and experiments.

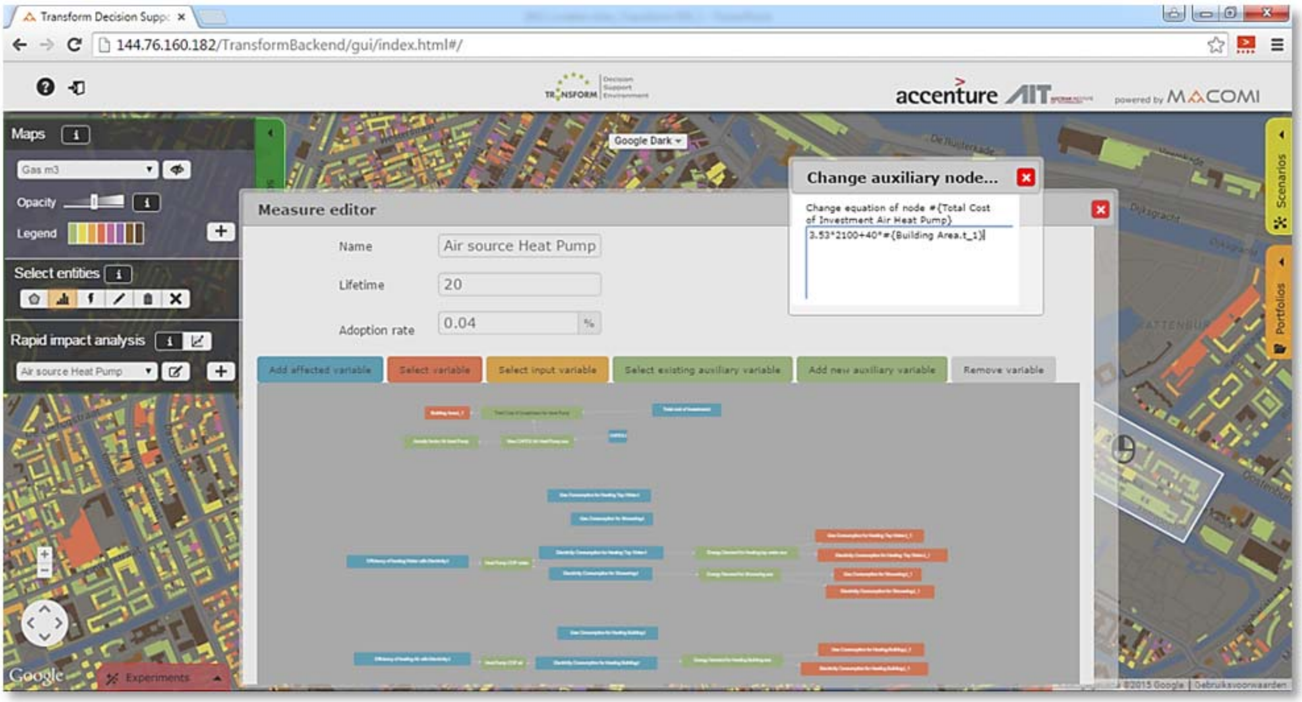

Fig. 2 Editing of measures

Following the KPIs and measures definition, interested stakeholders can combine measures to create different measure portfolios, mimicking actual decision making processes within the specific context of a city. Measure portfolios as well as individual measures can be allocated and applied to selected districts, streets, blocks or individual buildings and the user can determine the timing, rollout speed, and penetration rate for each of the allocated measures. Allocation can be done by selecting the area by drawing a freehand polygon directly on the map in addition to using a variety of selection criteria (e.g. energy label of buildings, ownership of buildings, or function of buildings). By combining different measure portfolios, alternative implementation actions and plans can be created, then simulated and evaluated.

By combining different scenarios and measure portfolios in time the users of the DSE can create and then run a number of different simulation experiments. Once simulations had been run, the stakeholders can view projected results in time (via detailed graphs, charts, and maps) and assess the impact of different implementation actions on achieving city's energy and climate targets. If the objectives had not been met, measuers can be iteratively adjusted and optimized leading to different measure portfolios and redefined implementation plans.

3.3 Example of a decision making processes supported by DSE. The case of Amsterdam Zuidoost

In Amsterdam - one of the TRANSFORM cities - the DSE was used in the Smart Urban Lab Amsterdam Zuidoost. It is a mixed-use area of about 300 hectares, including the Ajax soccer stadium, offices, enterprises, leisure and entertainment industry, shopping malls, academic hospital, data centers, residential areas, and an energy plant. The business activities are key contributors to the high energy consumption in the given area.

Fig. 3 Impact Analysis

The key challenge that Amsterdam Zuidoost is facing is the gap between current CO_2 emissions and the ambitious CO_2 reduction targets (55% reduction by 2025, and 81% reduction by 2040). In addition to the targeted CO2 reduction, the ambition of Amsterdam Zuidoost is to become a self-sufficient neighborhood where energy is produced locally, from renewable sources and from waste, and where energy losses are minimized to the maximum extent possible.

The stakeholders within the Zuidoost Smart Urban Lab have worked together to develop an energy vision and multiple project plans, but they lacked an insight in what would be the actual impact of these projects on the reduction of CO2 emissions, and how much each plan would contribute to reaching of other sustainability targets. Through application of TRANSFORM DSE a quantitative insight was generated, focusing on the following key measures: insulation and window replacement, LED lighting and sensors, solar PV panels, aquifer thermal storage, and wind turbines.

As the base case scenario, the TRANSFORM DSE was used to define the maximum potential of the area by assuming that all building owners were willing to contribute to the energy transition, by implementing one or more suitable sustainability measures in their buildings. Second scenario was the case in which serious effort would be needed to convince stakeholders to implement sustainability measures, but not up to the level of persuading every single actor to cooperate. As some of the stakeholders indicated, it is often easier to align a smaller group of large actors than a large group of small actors, like households. Third scenario was a more pessimistic one, with minimum uptake rates that were deemed achievable under any circumstances.

The base scenario (the theoretical maximum) has demonstrated that there is enough potential in the area to reduce emissions below the 2025 targets and that the reductions in consumption costs would outweigh the investment costs. Second scenario, with large players aligned through a joint initiative and smaller actors having a relatively high willingness to transform their buildings, and has demonstrated that the climate targets would be easily reached, in fact, the results differed only marginally from the maximum potential scenario. Third scenario (a very pessimistic case), in which only few building owners are willing to contribute to the energy transition, has demonstrated that none of the targets would be fully reached, energy costs would remain high, but there would be still a significant (36%) reduction in CO_2 emissions.

The experience in TRANSFORM project has showed firstly, that DSE application enabled the city stakeholders to get a number of insights that were significantly different from their initial top down study, which was done prior to the availability of the Decision Support Environment. Initial study assumed a reduction of 20% in emissions due to the change of building behaviour in energy consumption and insulation measures. A more detailed analysis supported by TRANSFORM Decision Support Environment, demonstrated that insulation and window replacement can reduce emissions in the area by maximum 6.2% (taking into account actual building dimensions and by insulating walls, floors, roofs and windows to the optimal level). By including LED lighting and motion sensors in larger buildings, a total reduction of 30.6% could be reached. This indicates that actual reductions from change of behaviour and insulation are very much dependent on the set of measures included in the definition of these terms.

Secondly, the analysis within a given environment provided insight into the realistic potential instead of the maximum theorethical potential, thereby not overestimating the impact of measures. Where the initial study identified a maximum energy consumption reduction potential of 293% (in theory generating more energy than consumed) due to aquifer thermal storage systems, the decision support environment has shown that a maximum realistic reduction potential is actually 34.2%.

Thirdly, the analysis has provided a better understaning of the role that the willingness of building owners' to apply different measures plays. Under the optimistic scenario, targets are easily reached, while under the pessimistic scenario none of the targets would be reached, but the impact would still be very significant. This provides city stakeholders with a useful understanding, that even with a low uptake, a diverse set of measures can still lead to significant improvements in the sustainability performance of an urban area.

4. Discussion

The experience in TRANSFORM project illustrates the potentials of more systematic and bottom-up approaches to analysis and planning of interventions in our built environment. Such modelling and simmulation tools like DSE expose the value of supporting instruments in making complex urban interrelations visible and accessible. Through linking of different urban dimensions (buildings, energy supply infrastructure, etc.) in a systematic and consistent manner, it is possible to gain valuable insights into co-rellating aspects of urban development and plan accordingly.

Although numerous urban modelling and simulation instruments exist, a dynamic linking of spatial and energy related information is still a challenge. Yet, the fields of urban and energy planning are experiencing a rapid merging and integration. The recognition that one has a significant impact on the other has penetrated the mindsets of numerous urban actors. In this context, the availability of more integrated and systematic methods of analysis, evaluation and planning of our built environment is still limited and far from common. DSE represents only one example, how understanding of differing energy consumption patterns allocated to specific urban typologies and configurations can provide essential insights and support in defining most suitable and effective measures in a given set of circumstances and potentially encourage their transformation.

The development process of TRANSFORM DSE has at the same time exposed significant deficits concerning the urban data situation. Our initial assumption at the project start about emmediate availability of a high quality energy and spatial data has proven not to represent the reality. The actual experience revealed that the data availability and quality in the six cities differed widely. Various inconsistencies regarding data policies became visible throughout the project, depending on the national context of partcicipating cities. The spectrum reached from very open data policies and availabilty of detailed data on building level to very scarce data, based on a few building blocks. In order to reach a better understanding of European cities' transformation capacities however, it is substantial to ensure a data related consistency thoughout Europe.

Significant steps have been undertaken in approaching the processes of urban transformation in a innovative and collaborative ways; however, there are quite a few challenges still ahead of us, requiring a continuous willingness to question the existing methods, policies and approaches again and again.

5. Conclusion

There need no longer be a gap between the 'hard' sciences, which speek of certitudes, and the 'soft' sciences which deal with possibilities. [7]
The achievements of the TRANSFORM project reach far beyond the development of the DSE, Transformation Agendas and Implementations Plans. Working together has invigorated new initiatives from which further collaborative efforts and networks can grow. This experience made it very clear, that the complexity inherent to urban developments has to be matched by the methods and approaches that are able to grasp and if necessary intervene in an appropriate manner, avoiding isolated approaches. Transformation requires an intergation of all dimensions, including stakeholders, information, tools, methods, etc. In particular the example of Amsterdam Zuidoost has exposed the synergies that an open approach to urban-energy planning can spark. Integrative and interdisciplinary collaboration is probably the most challenging but also most rewarding experience we can make.

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"degewo Zukunftshaus": Concepts for sustainable energetic rehabilitation of buildings

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Summary

An 8-storey apartment building with 64 apartments, erected in the 1950s, shall be refurbished to the so-called „Zukunftshaus“, or „house of the future”. Fundamental objectives are a high proportion of energetic self-sufficiency for the operation of the building, and a high portability of the conceptual and technical solutions to other buildings. A consistent low temperature concept is the key to success besides an optimized usage of available areas for solar energy technologies. In the end, the building will be completely self-sufficient w.r.t. it’s own operation. A considerable part of the user’s energy demand will be covered as well.

Keywords: energy concept, low temperature concept, building renovation, self-sufficiency

1. Motivation

Berlin's largest housing company, degewo, is in the process of rehabilitation of an 8-storey apartment building with 64 apartments, erected in the 1950s, to the so-called „Zukunftshaus“, or „house of the future“(see Figure 1 and Figure 2). Fundamental objectives are a high proportion of energetic self-sufficiency for the operation of the building, and a high portability of the conceptual and technical solutions to other buildings of the housing company. Start of construction is planned for the end of 2015, operational start and moving into the renovated building for early 2017. This paper describes the development of an energetically sustainable and lasting approach for the degewo project by the HTW Berlin – University of Applied Sciences.

2. Background

The self-sufficiency goal essentially means two things: reduction of the energy demand to a minimum and providing a maximum of renewable energy generated on the building to meet the remaining needs. Minimizing the energy demand is crucial for buildings of this size. This was determined within the framework of a master's thesis at the HTW Berlin [1, 2], in which residential and office buildings with a floor space of about 3,500 m² of different dimensions, orientations and window sizes are examined using extensive dynamic building simulations. In the study, all suitable roof and facade surfaces are available for photovoltaic power generation. This power shall be used for the entire operation oft he building, especially also for the operation of a heat pump to match the heating demand. In addition, it is intended to cover the electricity demand caused by the user. This supply approach is not mandatory, but does not restrict the generality of the self-sufficiency approach.

Figure 1: The existing building today (Source: degewo)

Figure 2: Visualisation oft he „degewo Zukunftshaus" after renovation (source: degewo)

As a result, the study comes to the conclusion that positive energy balances (energy generation exceeds the annual total consumption) are possible only with long, rather flat and unshaded building geometries with modest window areas, but not with a compact design as given in the degewo project. Thus, it is clear a priori: It will not be possible to completely meet the energy demand by renewable energy generation on the building's surface. The objective is therefore adapted in such a way that the self-sufficiency goal is restricted to the pure building operation for heating, ventilation, cooling and general power. In addition, as much of the user's electricity demand within the apartments shall be met. Conclusion: The demand reduction must be taken very seriously and state-of-the-art efficiencies for the renewable energy generation are mandatory.

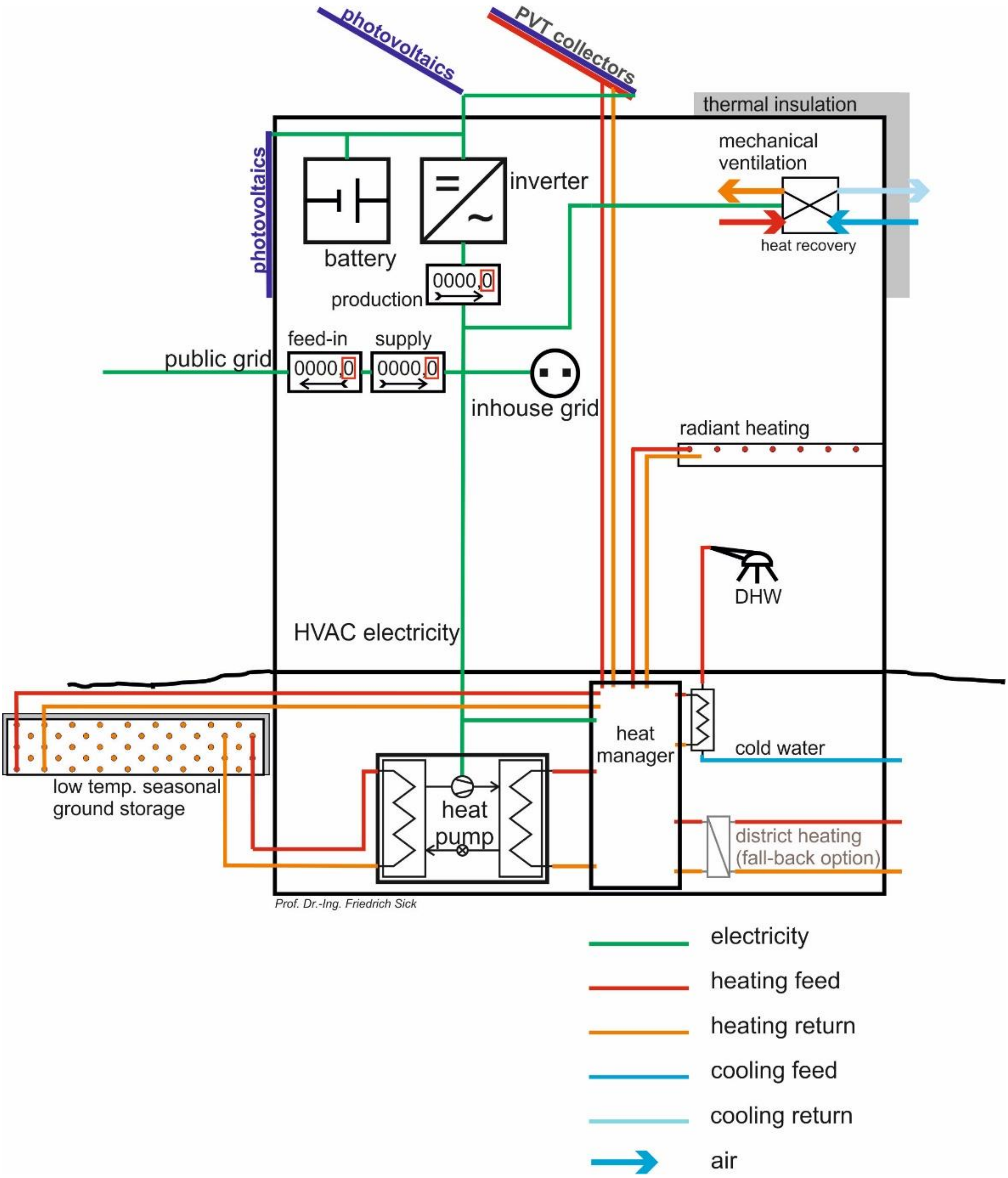

Figure 3: Schematic of the energy supply concept in the „degewo Zukunftshaus", winter case (source: HTW Berlin, Prof. Sick)

3. Concept development

In a multi-stage process four concepts are developed, simulated energetically, roughly calculated economically, and presented to the client. At the end of a discussion process between degewo, the *Drees & Sommer* project managers and the HTW Berlin, the refurbishment conception represented in Figure 3 is selected. It is based - as with the other proposals – on a very good thermal insulation of the building envelope and a mechanical ventilation system with heat recovery. Other key elements of the concept are: maximum power generation on the building envelope, electricity storage and a consistent low temperature concept in combination with a ground heat store that allows for high efficiencies of the solar technologies and best COP values of the heat pump. The heating distribution uses a radiant ceiling heating, which can be used also for cooling in the summer. The use of combined PV-thermal (PVT) collectors leads to a better area efficiency for solar technologies. An implemented heat manager works on the principle of "consumption prior to storage".

4. Design and implementation planning

Currently, the project is in the planning phase. During this and the previous design stage, the concept is worked out in more detail.

4.1 Building shell

The earlier applied 8 cm thick heat insulation is reinforced by another 12 centimeters. New windows are triple glazed. The existing balconies are separated and replaced by larger constructions placed in front without any thermal bridges.

4.2 Ventilation

Each apartment receives a mechanical supply and exhaust air system with heat recovery. In this way the heat loss through the ventilation system is minimized.

4.3 Solar energy

The thus minimized building energy demand shall be met as far as possible by renewable energies. The necessary and suitable areas for solar thermal and electric production are located on the roof and in parts of the facade. The roof surface is covered as far as possible with photovoltaics (PV), taking into account maintenance accessibility. This means that a maximum roof usage and energy yield is chosen rather than a maximum solar efficiency w.r.t. the modules. This is acceptable with today's PV prices and leads to much higher solar fractions. For reasons described below, the use of solar thermal energy is required. To avoid a competition concerning the available area, parts of the PV area is covered with PVT elements. PVT photovoltaic thermal hybrid collectors produce both solar power and – with reduced efficiency - solar heat.

4.4 Electricity storage

The building remains connected to the public electrical power grid. PV power surpluses are fed into the grid. At times of insufficient PV production the building is supplied by the grid. However, a battery storage is provided for an increased direct use of PV electricity. An innovative vanadium redox flow battery is selected, characterized by the lack of any self-discharge. Thus, there is no charge reduction as with other technologies during standstill times.

4.5 Heat pumps

The PV power operates two compression heat pumps: one for the domestic hot water and one to heat the building. For high efficiencies - expressed by the COP, the ratio of generated heat to inserted electrical energy over a year - high temperatures of the heat source and low temperatures of the heat sink are mandatory. The heat source is the ground under the building, the heat sink in case of heating the heating medium. To raise the soil temperatures, a low-temperature ground storage is used. A radiant heating system must be realized for low feed temperatures in the heating medium.

4.6 Low temperature store

The low temperature store consists of nothing else than the soil itself and is placed right next to the building. Durable plastic pipes buried in the ground up to a depth of 1.5 m below the surface serve as heat charge and discharge units while flown-through by water. The store is thermally insulated laterally and upwards. The insulation itself provides for an increased temperature compared with the undisturbed soil. In addition, heat from the PVT collectors is fed into the store. Because temperatures in the low 1- and 2-digit Celsius range are already suitable for this purpose, collector output is usable even under unfavourable irradiation and outdoor air temperature conditions. This leads to high efficiencies. Also summer excess heat from the apartments can be stored in the ground. The apartments are cooled to comfortable temperatures, an unusual feature in buildings of this type.

4.7 Radiant heating

In the existing building traditional radiators are mounted. They require relatively high feed temperatures even with a good thermal insulation standard as is given here. To minimize these temperatures for an effective use of the heat pump, a surface heating system will be installed instead. Underfloor heating systems, which operate according to this principle are common in new buildings nowadays. In the renovation, they are difficult to implement: expensive removing/exchanging of the floor screed would be necessary for keeping the room height, whereas transitional problems would arise on the doorsteps in case of an added heating screed on top of the existing floor. For this reason, a radiant ceiling heating is planned which has also some advantages over underfloor heating. For example, furniture does not "disable" its function. Useful additional effect: In the summer heat from the apartments can be removed using this system and fed into the ground store. The tenant receives a (apart from the pump current) free and quite unusual comfort enhancement through summer cooling.

4.8 Heat manager

A central heat manager continuously checks the heat demand for heating and domestic hot water (DHW), the heat supply and the appropriate temperature levels. According to the principle of "Consumption prior to storage" a consumer is supplied directly with heat whenever possible avoiding the "detour” through the storage which always means additional losses. This also increases the overall efficiency.

5. Conclusions

The consistent low temperature concept in the degewo project is the key to success: the low-temperature store with temperatures slightly above its surrounding soil has little thermal losses and uses heat on a low-temperature level. Solar thermal energy may thus be used much more efficiently. Excess heat from the apartments during summer adds to the storage and offers free and unexpected summer comfort. The low temperature heating system is responsible for this. The combination of both low temperature technologies leads to unusually high COP figures of the heat pump and thus correspondingly low power requirements. Thus, the PV area necessary for HVAC is kept low so that still a large part of the user’s electricity demand can also be covered.

The primary energy (PE) balance is illustrated in Figure 4: provided the building would be renovated according to the 2009 building code – still valid at the beginning of the project's conceptual phase, the PE requirement decreased from today's 1100 to 920 MWh a year. In these figures, the user's electricity is included and constitutes around 50%. As planned now, the PE demand is reduced to 470 MWh/a. It is striking that no district heat or fuels must be acquired any more, that the complete electricity for HVAC, lifts and general lighting in staircases etc. plus a noticeable proportion of the (estimated) user's electricity is also covered. The dependencies with respect to energy are a lot lower both in volume and in terms of the number of providers.

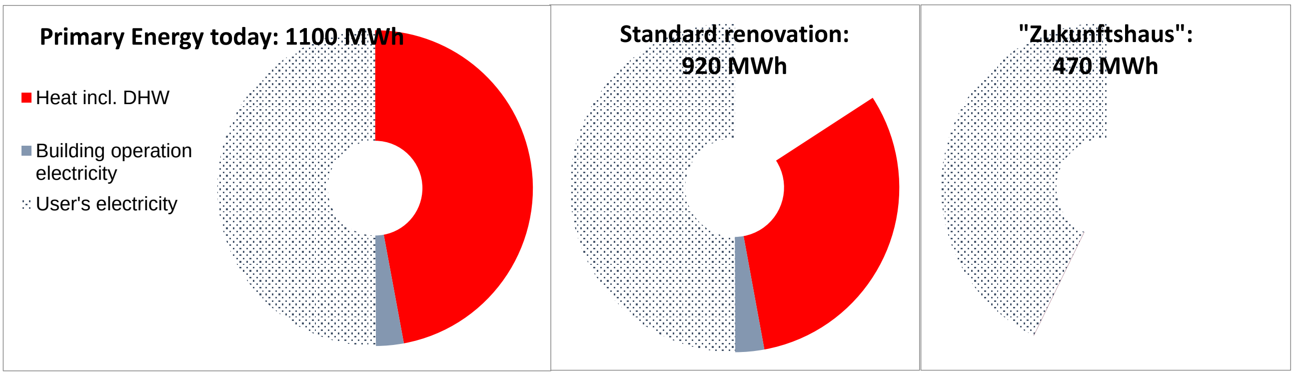

Figure 4: Comparison of the annual primary energy balance in the existing building, a conventional refurbishment and in the degewo "Zukunftshaus" project (source: HTW Berlin, Prof. Sick)

6. References

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Design for minimum life cycle energy and emissions (minLCee) building

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Summary

This paper has IEA Annex57 as backdrop, which investigates embodied energy and CO_{2eq} in building construction. Calculations support design feasibility studies for a minimum life cycle embodied energy and emissions (minLCee) demo building in Brazil. A meaningful lifecycle perspective is based on the cumulative energy demand (CED) concept to explore energy neutralization scenarios beyond operation stage. Production cycle modeling used the authors' primary data as well as secondary data collected from national literature and manufacturers brochures or adapted data from SimaPro 7.3 built-in Ecoinvent v 2.2, ELCD v 2.0, US LCI v.1.6 and Industry Data v.2.0 datasets. Energy Plus e Homer Energy software simulations respectively supported calculations of operational energy consumption and sizing of the different PV system technologies studied. Raw material supply and product manufacturing (43%) and the use stage (52%) dominate lifecycle CED. Neutralization of the total operational electricity plus the non-renewable CED embodied in building products is understood as the highest achievable goal for the building's current design. Beyond this threshold, extra land use would be necessary for PV installation.

Keywords: net zero energy; life cycle assessment; building life cycle; NZEB, CED

1 Introduction

This paper has the International Energy Agency (IEA) Annex57 as backdrop, which investigates embodied energy and CO_{2eq} in building construction. The past decades have focused on increasing operational energy efficiency levels. As top operational performance became mainstream, focus has shifted to the proportional share of (grey) energy embodied in the products stage and in end of life processes. Existing databases and much of the literature provide data for the embodied impacts in product stage. In fact, there seems to be a consistent shortage of data across the construction sector on the energy used during all lifecycle stages (Moncaster; Song, 2012). Transport to site is a big grey area and its accurate description demands continuous and close interaction with logistics and transport sectors. Prediction of energy use during standard site operations becomes a fundamental part of the whole life embodied energy equation, which has been hampered by a lack of general data on energy intensity of construction equipment and activities, as well as on energy savings related to optimized site management operations. From all renewable energy sources, photovoltaic (PV) solar energy is the one that currently shows the fastest growth rate. PV is considered one of the cleanest sources of energy available, being the environmental impacts basically restricted to the manufacturing and disposal phases of the equipment lifecycle (Fthenakis; Kim, 2011). From literature reviewed, though, this embodied impact fraction is seldom acknowledged in neutralization calculations. Finally, a clear understanding of the service life of individual components is necessary to support calculations of maintenance/repair/replacement/refurbishment as part of the use stage. There is also limited data on the energy used by demolition, reuse and recycling processes at the end of life of a building.

2 Purpose and methodological approach

2.1 Overview

This research was developed in four main parts: (i) modeling production cycles of building products used in the selected case study; (ii) detailed modeling of the building lifecycle; (iii) calculation of cumulative energy demand (CED) for the different lifecycle phases, using the CED method and SimaPro 7.3 LCA support platform; (iv) modeling of PV systems comprising four different technologies, using Homer Energy software simulations.

The selected case study building is the (minLCee) Living Lab, designed for the University of Campinas – Brazil. The building's design incorporated low-energy strategies, integrated design process, resource use optimization, onsite renewable energy technologies and storm water management, low energy refrigerating system, online resource use and indoor monitoring, among other best practices. The overall system boundary established for lifecycle modeling in this study spans between Modules A1 and C2, shaded in Fig. 1.

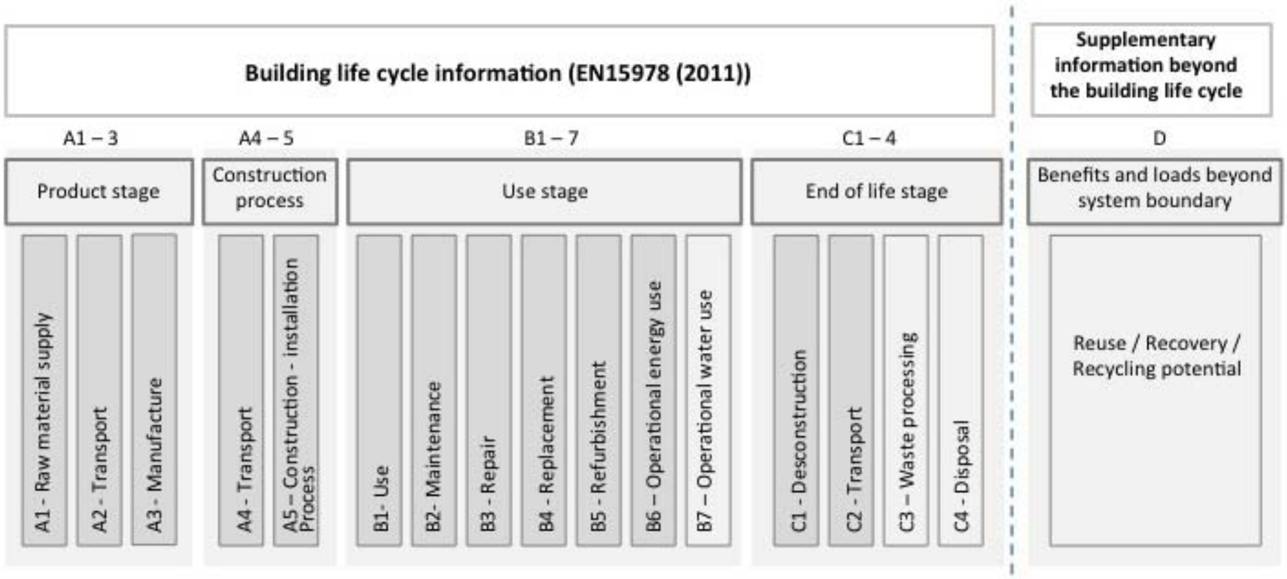

Fig. 1. Building life cycle information stages and respective modules (BS EN 15978, 2011).

Operational energy consumption was simulated using Energy Plus. Ten neutralization scenarios (Table 1) using four different PV technologies were preset. As the NZ(CED)B Plus status (i.e.: compensation of total operational electricity - net zero (NZ) - *plus* non-renewable CED of building products) was originally targeted, neutralization goals were then increased by adding compensation of the non-renewable portion of the primary energy embodied in raw material supply and manufacturing of building products. Finally, requirements to achieve two LC(CED) scenarios were also checked.

Table 1. Compensation scenarios analyzed

Building lifecycle stage		**Renewable energy generation targets**
Operation (net zero, NZ) statuses		*The PV system must produce enough energy to compensate*
Operational Eletricity (NRen)	NZ(Emission) B (Torcellini et al, 2006)	The building annual non-renewable operational energy consumption
Operational Eletricity (Total)	NZ(E)B (Torcellini et al, 2006)	The total building annual operational energy consumption
CED of Operational Eletricity (NRen)	NZ(CED_{NRen}) Building	The non-renewable portion of the cumulative energy demand of Brazilian mix, grid-supplied operational electricity
CED of Operational Eletricity (Total)	NZ(CED) Building	The total cumulative energy demand of Brazilian mix, grid-supplied operational electricity
Beyond Operation *Plus* statuses (+ CED_{NRen}PROD)		*The PV system must produce enough energy to compensate…*
Operational Eletricity (NRen) + CED (NRen) of Building Products	NZ(Emission)EB Plus	The building annual non-renewable operational energy consumption *plus* the non-renewable portion of the cumulative energy demand of building products
Operational Eletricity (Total) + CED (NRen) of Building Products	NZ(E)B Plus	The total building annual operational energy consumption *plus* the non-renewable portion of the cumulative energy demand of building products
CED of Operational Eletricity (NRen) + CED (NRen) of Building Products	NZ(CED_{NRen})B Plus	The non-renewable portion of the cumulative energy demand of Brazilian mix, grid-supplied operational electricity *plus* the non-renewable portion of the cumulative energy demand of building products
CED of Operational Eletricity (Total) + CED (NRen) of Building Products	NZ(CED)B Plus	The total cumulative energy demand of Brazilian mix, grid-supplied operational electricity *plus* the non-renewable portion of the cumulative energy demand of building products
Lifecycle statuses		*The PV system must produce enough energy to compensate…*
Lifecycle CED (NRen)	LCNZ(CED_{NRen})	The non-renewable cumulative energy demand *over the whole building's lifecycle*
Lifecycle CED (Total)	LCNZ(CED)	The total cumulative energy demand *over the whole building's lifecycle*

2.1 Building lifecycle modeling

The CED calculation is based on the method published by ecoinvent version 1.01 (Frischknecht; Jungbluth, 2000). As implemented in SimaPro (PRé, 2008), characterisation factors are given for the energy resources in five impact categories, expressed by the renewable (biomass, wind/solar/geothermal and water) and non-renewable (fossil and nuclear) CED components. The CED, expressed in MJ, of each stage of the building's lifecycle was calculated by using Equations 2a to 6a and aggregated for whole lifecycle figures (Equation 1a).

$$CED_{LC} = CED_{PROD} + CED_{TR} + CED_{CON} + CED_{OP} + CED_{EOL} \quad (1a)$$

Where CED_{LC} stands for lifecycle Cumulative Energy Demand, in MJ; CED_{PROD} is the CED of extraction/manufacturing of the building products, in MJ (Equation 2a); CED_{TR} is the CED of transport activities, in MJ (Equation 3a); CED_{CON} is the CED of construction activities, in MJ (Equation 4a); CED_{OP} is the CED of operation activities, in MJ (Equation 5a); CED_{EOL} is the CED of end of life (EOL) treatment activities, in MJ (Equation 6a).

Product stage (Modules A1 and A3)

CED_{PROD} (Modules A1 and A3) was calculated using Equation 2a.

$$CED_{PROD} = \sum_{i=1}^{n} Q \ x \ CED_i \quad (2a)$$

Where CED_{PROD} stands for Cumulative Energy Demand, in MJ, of extraction/manufacturing of the building products; Q is the consumed quantity of a given building product (in mass, volume or area); n is the number of building products; CED_i is the specific CED, in MJ, per building product functional unit (kg, m^3 or m^2).

Based on the construction drawings and bases of design (BODs) documented for the Living Lab, the materials and components included in the design were quantified and inventory data sourced for the best possible match. With the exception of concrete (authors' data) and the green roofing system (manufacturer's brochure), materials and components production processes were adapted from Ecoinvent v.2.2, ELCD v.2.0, Industry Data v.2.0 and US LCI v.1.6 databases (PRé, 2008). Ecoinvent database v.2.2 (Ecoinvent, 2007) offered information for most items and was preferred for consistency sake, but merging different inventory databases and secondary sources was unavoidable.

Construction process stage

Freight and CDW transport

CED_{TR} of freight transport registered within the supply chain (Module A2) and later on in the construction process stage (Module A4) was calculated using Equation 3a.

$$CED_{TR} = \sum_{i=1}^{n} M \ x \ D \ \ x \ CED_i \quad (3a)$$

Where CED_{TR} stands for Cumulative Energy Demand, in MJ, of transport activities; M is the transported mass, in tones; D is the travel distance, in km; n is the number of freight modals used per transport functional unit; CED_i is the specific CED, in MJ, per transport functional unit (tkm) of the used type of fuel and modal autonomy.

CED_{CON} of construction activities (Module A5) was calculated using Equation 4a.

$$CED_{CON} = \sum_{i=1}^{n} C \ \ x \ CED_i \quad (4a)$$

Where CED_{CON} stands for Cumulative Energy Demand, in MJ, of construction activities; C is the construction item/activity considered, in respective functional unit; n is the number of construction items/activities; CED_i is the specific CED, in MJ, per construction item/activity functional unit.

Transported mass and transportation distances were included either accurately based on actual travel distances or on best of knowledge estimations in case of missing information. Data from

Ecoinvent v.2.2 and ELCD v.2.0 databases were used for modals and fuel types. The original material mass and corresponding transportation and material usage impacts were corrected using wastage factors derived by Agopyan et al (n.d.) or observed in actual construction practice. Since the case study is not built yet, construction equipment fuel use was estimated using data for consumption per m^2 of gross floor area (Yan et al, 2010) for a high-rise building in Hong Kong. Even though construction practices may differ significantly from the original context, as well as the fuel intensity for high and low-rise building construction, Brazilian data for construction activities separated from materials usage are not readily available, and a potentially more suitable figure was not found in the literature reviewed.

Use stage (Modules B1-B6)

CED_{OP} of the use stage was calculated using Equation 5a, by adding contributions from maintenance/repair/replacement (Modules B1-B5, i.e. material intake and transportation to the building, as well as corresponding CDW transport to EOL treatment) and operational use of energy (Module B6, 100% electricity).

$$CED_{OP} = \sum_{i=1}^{n} Op \ x \ CED_i \qquad (5a)$$

Where CED_{OP} stands for Cumulative Energy Demand, in MJ, of use and operation activities; Op is the operation item/activity considered, in respective functional unit; n is the number of operation items/activities; CED_i is the specific CED, in MJ, per operation item/activity functional unit.

Operational energy consumption was simulated using Energy Plus. Data from Ecoinvent v.2.2 (Ecoinvent, 2010) for low voltage electricity in the Brazilian mix were used for operational electricity impact calculation. Substitution of building products during the building's service life (Use stage, in Fig. 1), was planed in accordance with the Brazilian performance standard (ABNT NBR 15575, 2013), which establishes minimum design service lives (DSL) for major building subsystems.

End of life stage (Modules C1-C2)

CED_{EOL} of the end of life stage was calculated using Equation 6a, by adding contributions from demolition/dismantling equipment energy use (Module C1) and from CDW transport to end of life treatment facilities (Module C2).

$$CED_{EOL} = \sum_{i=1}^{n} EOL \ x \ CED_i \qquad (6a)$$

Where CED_{EOL} stands for Cumulative Energy Demand, in MJ, of end of life (EOL) treatment activities; EOL is the end of life item/activity considered, in respective functional unit; n is the number of end of life items/activities; CED_i is the specific CED, in MJ, per end of life item/activity functional unit.

Two EOL scenarios were considered (Table 2): *(1)* demolition as usual (BAU, 0% reuse | 76% recycling | 23%landfill), with 90% of material recovery rate, followed by crushing of concrete, recycling of metals as scrap and incineration of wooden material without energy recovery and landfilling of the remaining CDW; and *(2)* 90%-recovery efficient selective dismantling (19% reuse | 60% recycling | 20%landfill), followed by partial (40%) reuse of steel frame, crushing of concrete, recycling of steel rebar and 60% of the structural frame and incineration of wooden material without energy recovery and crushing of uncoated glass, and landfilling of the remaining CDW.

Table 2. Description of the two EOL scenarios simulated

EOLS1 – CDW transport to EOL treatment - Scenario 1

EOLS1 - Demolition equipment	**Diesel consumption**	2880	liters
CDW treatment (BAU: 0% reuse | 76% recycling | 23% landfilling)	**Transport Distance (Km) road - one way**	**Mass (ton)**	**% total CDW (in mass)**
Recycling (90% of steel, concrete, aluminum)	25	1,347.49	76%
Incineration w/o energy recovery (90% of wood)	25		1%
Landfill Class I and II (100% gypsum/other)	25	26.71	2%
Landfill CDW	25	372.15	21%
Total CDW		**1,763.52**	**100%**

EOLS2 - CDW transport to EOL treatment - Scenario 2

EOLS2 – Dismantling equipment	**Diesel consumption**	5760	liters
CDW treatment after selective dismantling (Opt: 19% reuse | 60% recycling | 20% landfilling)	**Transport Distance (Km) road - one way**	**Mass (ton)**	**% total CDW (in mass)**
Reuse (60% steel frame)	10		19%
Recycling			60%
90% steel rebar + 30% frame (scrap)	10	206.52	
90% concrete, uncoated glass, aluminum, gypsum	25	803.23	
100% PV panels (glass, aluminum)	100*	13.10	
Incineration w/o energy recovery (90% wood)	25	17.17	1%
Landfill Class I and II			1%
10% gypsum	25	6.34	
100% other	25	10.23	
Landfill CDW	25	333.22	19%
Total CDW		**1,763.52**	**100%**

**Assumed to be available in 50 years from now.*

2.2 Energy demand scenarios and photovoltaic (PV) system modelling

Four crystalline silicon (single-Si, multi-Si) and thin film (amorphous-Si and CIGS) PV technology generations were simulated. Actual efficiency of PV modules is reduced when the panel is subjected to outdoor temperatures above the standard test conditions[1]. The extent that the efficiency is affected is described by the maximum power temperature coefficient (γPMPP), expressed in *%/K* (Table 3). The PV system sizing procedure using Homer Energy software discounted generation losses as the orientation and exposure angle of the computed envelope surfaces varied for facade- and horizontal rooftop-mounted applications (Table 10). A degradation factor of 0.5% per year was applied to account for generation loss through time, assuming a 25-year panel ser-

[1] Solar cell temperature of 25 ± 2°C; radiation level of 1,000 W/m^2 normal to the surface and solar spectrum of 1.5 AM (Ruther, 2004)

vice life (Lima et al, 2012) to ensure that the desired performance is maintained over the whole period of study.

Table 3. Characteristics of different PV modules. Technologies simulated here are highlighted (Fthenakis; Kim, 2011; EPIA, 2011; Makrides et al, 2009: Ito et al, 2008; Bravi et al, 2011)

PV technology	**Module Efficiency**	γP_{MPP}
single-Si	**12% a 19%**	**-0.42%/K a -0.56%/K**
multi-Si	**11% a 15%**	**-0.40%/K a -0.49%/K**
a-Si	**4% a 8%**	**-0.19%/K a -0.20%/K**
a-Si/μ-Si	7% a 10%	-0.33%/K
CdTe	10% a 11%	-0.22%/K
CIGS	**7% a 12%**	**-0.36%/K a -0.42%/K**

4. Results presentation and discussion

The structural system (41% of total CED), partitions (34%, particularly from galvanized steel frame), the PV system plus BOS (16%) and façade panels (7%) were the major contributors to CED embodied in building products accounted for in the Product stage. Raw material supply and manufacturing (43%) and the use stage (52%) clearly dominate lifecycle CED (Table 4). Material replacement and transportation of the corresponding CDW mass between the project site and EOL treatment facility increase the CED during use stage by a factor of more than four. EOL treatment scenario simulations proved to be very speculative, but whichever combination of deconstruction approach and material recovery for EOL treatment tested had negligible effect on CED (<1% CED_{LC}).

Table 4. Calculated CED_{Ren} and CED_{NRen} for the building lifecycle. For reference, results for the two EOL scenarios investigated are also presented

Product Stage (Modules A1, A3)	**CED_{Ren} (MJ)**	**CED_{NRen} (MJ)**	**Total CED (MJ)**
Raw material supply (Module A1) and manufacturing (Module A3)	**3,949,090.61**	**14,900,974.67**	**18,850,065.28**
Construction Process Stage (Modules A2-A5)	**CED_{Ren} (MJ)**	**CED_{NRen} (MJ)**	**Total CED (MJ)**
Transportation to manufacturing gates within supply chain (Module A2*) and to construction site gate (Module A4)	**13,102.47**	**938,082.67**	**951,185.13**
Construction – installation (Module A5)			
Material wastage during construction	99,955.38	606,206.21	706,161.59
CDW treatment (102.29 tones), transported 25 km (municipal facility)	65.35	5,036.75	5,102.10
Earth (547.2 tones), transported 25 km (municipal facility)	393.81	30,354.46	30748.27
Earth removal equipment (547.2 tones)	**129.04**	**44,317.88**	**44,446.92**
Construction equipment	162,626.33	337,904.41	500,530.74
Use stage (Modules B2-B6)	**CED_{Ren} (MJ)**	**CED_{NRen} (MJ)**	**Total CED (MJ)**
Material replaced in Maintenance/Repair/Replacement/Refurbishment (334.52 tones)	**1,552,653.13**	**11,445,458.00**	**12,998,111.14**

Module B6 - Operational use of (electric) energy (111,157.20 MJ_{elec}/yr)	***6,753,290.10***	***3,081,714.16***	***9,835,004.26***
End of life stage (Module C1-C2)	**CED_{Ren} (MJ)**	**CED_{NRen} (MJ)**	**Total CED (MJ)**
EOL Scenario 1 - 90%-efficient recovery (concrete and metals) demolition (1,763,52 tones) (76% recycled/23% landfilled)	387.11	132,953. 64	133,340.75
CDW (1,763.52 tones) transported to various destinations	944.14	72,773.35	73,717.50
Total EOL Scenario 1	**12,532,637.46**	**31,595,776.20**	**44,128,413.66**
EOL Scenario 2 – 90%-recovery efficient Selective dismantling (19%reuse/60%recycled, including PV panels/20%landfilled)	1,161.32	398,860.93	400,022.25
CDW (1,763.52 tones) transported to various destinations	972.43	74,953.78	75,926.21
Total EOL Scenario 2	**12,533,052.86**	**31,730,910.27**	**44,263,963.13**

[a] Most material wastage factors were extracted from Agopyan et al (n.d.). For items not covered, manufacturers' information and observed practice were used whenever available.

Table 5 shows the results for the ten energy balance scenarios simulated, which ranged from net zero to complete building life cycle. Offsetting the non-renewable portion *[Scenario 1, NZ(Emission)EB]* and total operational electricity *[Scenario 3, NZ(E)B];* as well as of the non-renewable portion *[Scenario 2, NZ(CED_{NRen})B]* and total operational electricity CED *[Scenario 4, NZ(CED)B]* are potentially achievable using all technologies but a-Si in the last case. This brings important flexibility to decision-making, particularly in terms of costs and smooth integration to architecture. Sizing of the PV array sufficient to cover the NZE Emission building (Scenario 1) makes it very evident that such concept does not stimulate much progress in contexts with high renewable content electricity mixes, like in Brazil. Though a-Si is most efficient technology in terms of system power demanded, and could be a good alternative for projects with more surface available, the single-Si PV technology is the most efficient alternative in terms of area needed to deliver each kWp. In fact, addition of the non-renewable CED embodied in building products to the neutralization targets ('Plus' statuses) basically rule out surface-hungry PV technologies. NZ(Emission)EB Plus status (Scenario 1a) is still achievable by using single-Si or multi-Si, but all remaining scenarios would only be accomplished if single-Si PV is used.

Table 5. Energy balance scenarios simulated and respective system power and effective area requirements for four PV technologies

PV Technology/scenarios	System power (kWp)	Effective generation area (m^2)	PV Technology/scenarios	System power (kWp)	Effective generation area (m^2)
1. Operational electricity (NRen) [NZ(Emission)EB]			**1a. Operational electricity (NRen) + CED (NRen) PROD [NZ(Emission)EB Plus]**		
single-Si	3.5	**20.59**	**single-Si**	64.47	**379.10**
multi-Si	3.49	24.94	multi-Si	64.29	459.06
a-Si	3.41	48.73	a-Si	62.77	897.03
CIGS	3.47	28.87	CIGS	63.81	531.52
2. CED Operational Eletricity (NRen) [NZ(CED_{NRen})B]			**2a. CED Operational Eletricity (NRen) + CED (NRen) PROD [NZ(CED_{NRen})B Plus]**		
single-Si	12.61	**74.14**	**single-Si**	**73.58**	**432.65**
multi-Si	12.57	89.78	multi-Si	73.38	523.9
a-Si	12.28	175.44	a-Si	71.64	1023.75
CIGS	12.48	103.95	CIGS	72.82	606.6

3. Operational electricity (total) [NZ(E)B]			**3a. Operational electricity total + CED (NRen) PROD [NZ(E)B Plus]**		
single-Si	22.74	**133.72**	**single-Si**	**83.71**	**492.22**
multi-Si	22.68	161.92	multi-Si	83.48	596.04
a-Si	22.14	316.41	a-Si	81.51	1164.71
CIGS	22.51	187.48	CIGS	82.85	690.13
4. CED Operational Eletricity (total) [NZ(CED)B]			**4a. CED Eletricity Operational total + CED (NRen) PROD [NZ(CED)B Plus]**		
single-Si	40.24	**236.62**	single-Si	101.21	**595.13**
multi-Si	40.13	286.53	multi-Si	100.93	720.65
a-Si	39.18	559.9	a-Si	98.54	1408.21
CIGS	39.83	331.76	CIGS	100.17	834.41
5. LC CED (NRen) [LCNZ(CED_{NRen})]			**5a. LC CED (total) [LCNZ(CED)]**		
single-Si	129.28	**760.17**	single-Si	180.56	**1061.69**
multi-Si	128.92	920.51	multi-Si	180.06	1285.63
a-Si	125.87	1798.73	a-Si	175.8	2512.21
CIGS	127.95	1065.81	CIGS	178.7	1488.57

The load curve of the operational electricity demand is pretty much adherent to that of PV's power production on a daily basis. All net zero (NZ) energy and CED statuses would be easily reached through PV onsite generation, so that no electricity would have to be drawn from the grid during operational phase on an annual basis, as established for net zero definitions. The desired NZ(CED)B Plus goal (Scenario 4a) was missed by little, and could possibly be achieved upon slight design or modeling improvement. Optimized usage of the current envelope area met the requirements for the NZ(E)B Plus *status* (Scenario 3a), able to offset the total operational electricity *plus* the non-renewable CED embodied in Product stage's building items. This is understood as the practical feasibility limit for the present design, given by the envelope surface available for PV mounting while keeping its architectural coherence. The corresponding 674.30 m^2 of installed single-Si PV was inserted in the building's CED lifecycle calculations (Table 4). Beyond this threshold, all scenarios simulated would require extra land use, particularly the Life Cycle Net Zero CED statuses (Scenarios 5 and 5a, Table 5), which depend on effective generation areas larger than the building's footprint and envelope area added together.

5. Conclusions and final remarks

The feasibility threshold for compensating the lifecycle CED of the studied minLCee building with a single-Si PV array proved to be the, onsite counterbalance of the total operational electricity *plus* the non-renewable CED embodied in building products (NZ(E)B *Plus* status). For being a demo building, the maximum generation capacity was basicaly limited by the available surface for applying traditional rooftop - and façade-mounted PV. In real-life implementation studies, cost would be probably a more important aspect restricting aggressive energy and GWP reducing goals. Ubiquitous use of visible PV panels sends a powerful message for passersby and is tuned with this particular building's mission, but would not necessarily suit other construction types. The use of BIPV was not explored and could bring further material intake benefits. This case does not represent the general practice in Brazil or even at the campus. The university's overall grid load is about 1000 times higher than the PV production. Furthermore, peak load hours in the country happen in the evening. No single building would be able by itself to significantly reduce the stress on the electricity grid and help the grid operator. However, this experience helps to ground concepts and shows that they are achievable in our context, as well as the major gaps and challenges to turn NZ goals into mainstream practice.

6. Acknowledgements

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Design phase calculation of greenhouse gas emissions for a Zero emission residential pilot building

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Summary

In this paper we describe the design phase process and measures for a zero greenhouse gas emission residentital building in Norway. The aim of the building is to go beyond a zero emission operational balance and include material emissions. With several design phase efforts to reduce and compensate emissions, a zero emission balance was nearly met for our case building. In our design phase evaluations we see that our approach is sensitive to methodology for material emission accounting and the choice of electricity emission factor for the import and export of electricity. In conclusion, we show the need for a methodology for emission calculations during the design phase of ZEBs that includes simple and solid rules for simplifications, service lifetimes and future scenarios.

Keywords: zero-emission buildings, design phase approach, embodied emissions, residential pilot, evaluation

1. Introduction

To minimize the use of resources and greenhouse gas emissions from the use of energy and materials, the concepts of zero-emission buildings and zero-energy buildings (ZEBs) have been developed. [1] defines a zero energy building as "*An energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy*". There is an increasing focus on life cycle based zero emission buildings, as presented in [2] and [3]. Within the Research Centre on Zero Emission Buildings in Norway, efforts have been made to define a zero-emission building that goes beyond the operational energy use [4] [5, 6]. Reviews of building LCAs reveal that the embodied emissions account for a larger share of the total emissions when moving towards low-energy and zero energy/emission buildings [7] [8]. This is due to the fact that the relative share of the material emissions compared to the operational emissions is increasing and that passive and active energy concepts tend to increase the material inputs into buildings. Case studies of life cycle ZEBs reveal that it is difficult to obtain a life cycle ZEB for residential buildings [3, 9] [10]. However, single-family residential buildings usually have larger areas available for energy production (e.g. solar modules) per heated floor area than more compact high-rise commercial buildings [11]. In this paper we describe and evaluate the design phase approach for a zero emission residential pilot building in Norway. The objective is to learn from the design phase experience in order to propose further improvements to the process. We describe our design phase approach and evaluate it through a discussion and examples with a focus on material emissions.

2. Methodology

The overall methodology is a simplified life cycle greenhouse gas emission accounting procedure based on [12, 13].

2.1 Goal and scope

The design phase goal was to identify measures that could reduce GHG emissions (kg CO_2eq) and provide input to the ZEB balance calculations. The ambition level chosen for the building was ZEB-OM as defined by [4] which can be described as follows: "*Emissions related to all operational energy use (O) plus embodied emissions from the materials and technical installations (M) are to be compensated by on-site renewable energy generation*." The approach used is similar to the one applied in [14] and [15]. The ZEB-OM and ZEB-O ambition levels are visualized in Figure 1 developed from [16]. The figure illustrates the increased focus on materials, where material emissions first need to be reduced, and then compensated for. We used the functional unit of 1 m^2 of heated floor area (200 m^2) over an estimated lifetime of 60 years.

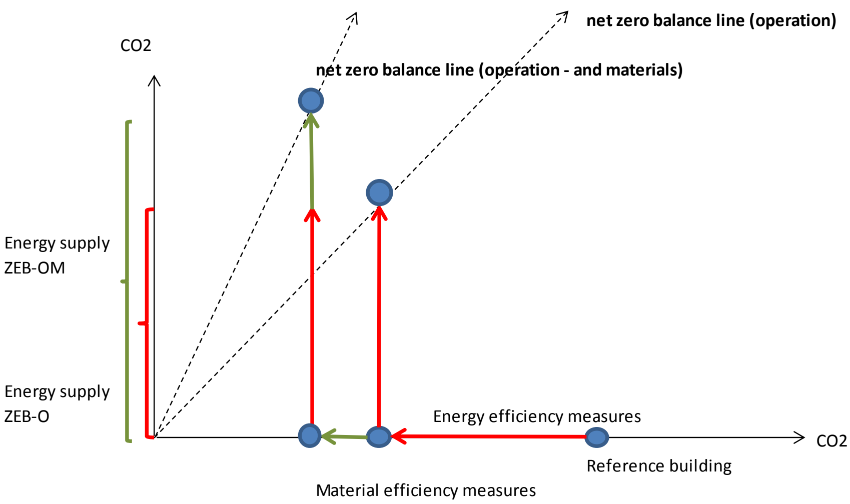

Figure 1 Illustration of the ZEB-O and ZEB-OM balance, energy and material efficiency and then emission compensation with renewable energy on-site, here the balance indicator is CO_2 emissions

A simplified life cycle emission balance over the estimated service lifetime is visualized in Figure 2, inspired by [17]. In our case, the production of materials (initial and estimates for replacement) as well as the energy use and energy production in the operational phase are included. The construction and demolition phases are excluded. The building itself was the physical boundary for the analysis.

2.2 Design phase workshops

The first design phase meeting was held in January 2013 and the design phase ended in a workshop in June 2013. Practical issues of building a ZEB were addressed in a series of interdisciplinary workshops arranged during the design process. Researchers from the Norwegian ZEB Centre were involved in the meetings. Working groups were initiated, dealing with the energy concept of the building, the construction concept, and the material concept. The different teams calculated different choices as inputs to the dimensioning of the concept and continued until a satisfactory balance was achieved.

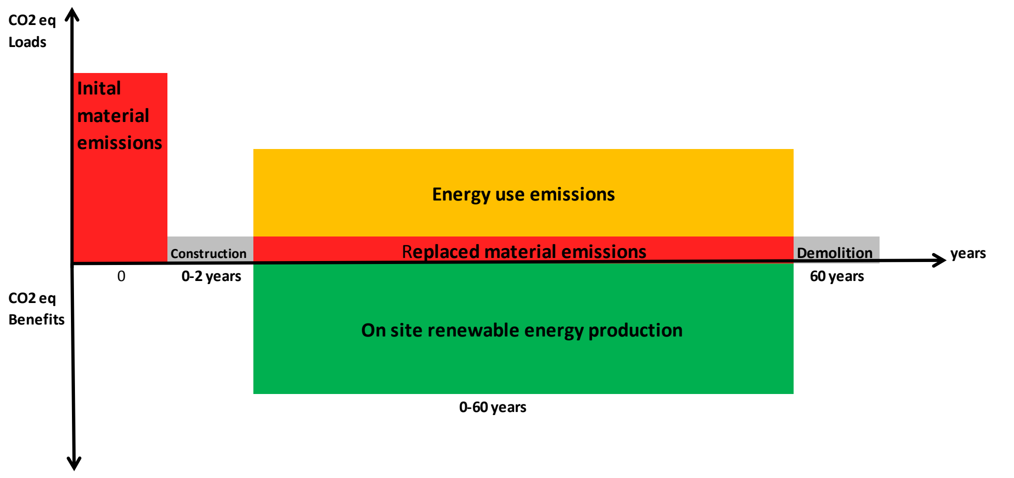

Figure 2 Zero emission life cycle balance approximation for a building, the green area with renewable energy production compensates for emission loads

2.3 Case building

Figure 3 A model of the house, Snøhetta architects

The case study is a two-storey single-family residential building designed by Snøhetta architects. A model of the building is shown in Figure 3. Comfort requirements are based on Saint-Gobain's multi-comfort concept [18]. The Norwegian companies Brødrene Dahl and Optimera were responsible for the energy concept and building construction, respectively. In Table 1, key dimensions are listed. The building was designed for use as a demonstration building of energy solutions.

Table 1 Key dimentions and simulation inputs

Description	Value	Description	Value
Location	59°12'N, 10°15'E	Total solar energy transmittance of windows	0.4
Available roof area	155 [m^2]	Mean annual ambient temperature	7.6 [C°]

Roof orientation	-45 (south-east)	Air leakage rate (n50)	0.3 [1/h]
Roof tilt	19°	Inside air temperature (set point)	20.3 [Cº]
Heated air volume	610 [m^3]	Mean solar radiation horizontal surface	111 [W/m^2]
Heated floor area	197 [m^2]	Ventilation air volume (mean value)	1.2 [m^3/hm^2]
Normalised thermal bridge value	0.03 [Wm^2/K]	Ventilation heat recovery efficiency	87%
Grey water heat recovery rate	50%	U-value roof	0.08 [W/(m^2K)]
Specific Fan Power (SFP)	1.3 [$kW/m^3/s$]	U-value ground floor	0.08 [W/(m^2K)]
Average power for lighting (LED)	1.0W/m^2	U-value windows and doors	0.73 [W/(m^2K)] (average)
Window and exterior door area	57 m^2	U-value exterior walls	0.1 [W/(m^2K)]

2.4 Material concept

Two main emission drivers were identified based on previous studies [19] the photovoltaic modules and the traditional concrete slab. To reduce emissions, the foundation slab was based on a timber and fibre plate construction. Underneath the timber slab is a strip foundation of low carbon concrete. Low carbon concrete is based on low carbon cement, which is partly based on fly ash substitution for clinker [20]. Reused bricks from a nearby construction site were used to increase the thermal mass for the building. Façade materials include painted Norwegian timber, stacks of fire wood, natural stone and reused bricks. Photovoltaic modules from Innotech Solar (ITS) (EcoPlus, Design Black 250W_p, 15.4% rated efficiency) were chosen due to their low carbon profile [21, 22]. The building has timber based bearings, with Norwegian glue-laminated beams. Timber was used also as the main material for surface coverings inside the building.

Table 2 Service lifetime scenarios

Component	**Service lifetime [years]**	**Component**	**Service lifetime [years]**
Photovoltaic panels	30	Floor material	15
Heat pump	20	Interior wall surface	30
Ventilation ducts	60	Insulation	60
Solar thermal system	30	Steel	60
Concrete	60	Windows/ doors	30

Building materials quantities were based on material take offs from the Building Information Model (BIM) made by the architects [23]. The life cycle analysis tool SimaPro version 7.3 was used for the material emission calculations [24]. Quantities of materials for technical installations and concrete and steel in the foundation were based on communcation with relevant professionals.

Material emission data used was from relevant Environmental Product Declarations (EPDs) ,from the Ecoinvent database v2.2 [25], and from the specific information from Innotech for the PV modules and Norbetong [20]. According to the ITS module emissions data by [21], the emissions are around 60 kg CO_2/m^2 module and we added 20 kg CO_2/m^2 as an estimate for the aluminum frame. We multiplied module emissions by 1.2 to include a scenario for the balance of system emissions (inverter, cabling etc.). This was based on the relative contributions between the balance of system and modules as analysed by [26]. Assumed service lifetimes are listed in Table 2. No emissions loads were accounted for the reused bricks. On site losses of materials were not accounted for.

2.5 Energy efficiency concept

The space heating demand of the house was minimized by designing a well insulated and air tight building envelope and a ventilation system with high efficiency heat recovery. The energy performance calculations were done according to the Norwegian standard NS 3031:2007 [27]. The lighting system was to be based on LED and good daylight utilization. Documention of the energy use was done by performing simulations with the Norwegian simulation tool SIMIEN [28]. Simulation inputs are given in Table 1.

2.6 Energy generation concept

The energy generation was based on roof mounted photovoltaic modules for electricity, and solar thermal modules for thermal energy. The photovoltaic system was to be connected to the local electricity grid and a local battery bank [29]. A geothermal heat pump (3kW) was to provide for 80% of the space heating and the remaining heat would come from the solar thermal panels. The heat was to be distributed through an underfloor heating system. Grey water heat recovery systems were also installed. It was estimated that the heat recovery rate from the heat exchangers would be 50%. The estimated energy output of the photovoltaic modules was simulated in PVsyst [30]. The design phase PV area was approximately 122 m^2. However, the final PV area was 150 m^2. The following simulation assumptions were made: first-year energy yield to represent all years (no degradion included), no significant shading, modules to be 100% snow-covered during December and January and 20% snow covered during November and February. The design phase energy yield from the solar thermal panels (8 m^2) was simulated using PolySun [31]. The final solar thermal panel area was 16 m^2.

2.7 Balance calculation

Emission payback calculations used a symmetric weighting approach as described in [16]. Thus, the same CO_2 equivalent factors were used for the import and export of electricity to and from the building. The building is designed as an “all-electric” building, which means that all energy exported or imported to the building is in the form of electricity. The net emission balance (ΔCO2) over the service lifetime of 60 years for an *all-electric* ZEB-OM can be formulated as in Equation 1:

$$\Delta CO2 = CO2_{mp} + CO_{mo} + CO2_{e}(Q_{d} - Q_{e}) \quad (1)$$

In Equation (1),

- $CO2_{mp}$ is the annualised **m**aterial emissions in the **p**roduct phase [kg CO_2 eq/m^2 per year]
- $CO2_{mo}$ is the annualised **m**aterial emissions during **o**peration (here product phase replacements only) [kg CO_2 eq/m^2 per year]

- Q_d is the annual electricity **d**elivered to the building [kWh/m^2 per year]
- Q_e is the annual electricity **e**xported to the grid from the building [kWh/m^2 per year]
- $CO2_e$ is the annually averaged CO_2eq **e**mission factor for **e**lectricity [kg CO_2eq/kWh]

If the net balance, ΔCO2, is zero or less, a zero-emission balance is achieved. The emission factor of 0.132 kg CO_2 eq/kWh electricity was used for $CO2_e$. This yearly averaged factor is based on a future scenario assuming a fully decarbonised European grid by the end of 2055, according to EU policy goals [4, 32].

3. Results

Design phase results were presented as annualized emissions over a service lifetime of 60 years per square metre of heated floor area. The combined results are shown in Figure 4. We calculated the emissions from the product phase to be 3.6 kg CO_2 eq/m^2 per year and the material replacement scenario 2.2 kg CO_2 eq/m^2 per year. In total, material emissions were 5.8 kg CO_2 eq/m^2. Around 2 kg CO_2 eq/m^2 were due to the photovoltaic modules and balance of system scenario. The simulated yearly specific energy demand resulted in is a total demand of approximately 70 kWh/m^2, where space heating (23.6 kWh/m^2), domestic hot water ((23.6 kWh/m^2) and technical equipment (15.8 kWh/m^2) were the largest contributors. Simulated total demand for electrical energy delivered to the building was 35 kWh/m^2 per year with annual total demand of 7045 kWh. First- year energy simulation yield of the ITS photovoltaic modules were 15000 kWh. This amounted to a yearly energy yield of 74 kWh per square metre of the useful floor area or 123 kWh/m^2 of module area. Applying our numbers to the ZEB balance equation 1, the ZEB balance is 3.6 + 2.2 + 0.132 kg CO_2 eq/kWh * 35kWh – 0.132 kg CO_2eq/ kWh * 74.1 kWh = 0.3 kg CO_2 eq/m^2. Thus, these values gave us a close margin on the ZEB balance.

3.1 Evalation of the design phase

Several measures to reduce emissions through material choices, energy efficiency, and renewable energy production were initiated during the design phase. This section includes an in retrospect evaluation of the methodological that was made in the design phase.

Calculations of energy performance: Simulated energy use values may differ from actual energy use based on aspects like occupant behaviour and technical performance of the components installed [33]. Also, due to the lack of time and appropriate tools, simplified assumptions often have to be made in the design phase. One such simplification in the design of the Multikomfort house was to assume that 50% of the energy in the grey water would be recovered with the heat recovery system. Also, the energy simulations included a number of assumptions with respect to the envelope air tightness, efficiency of ventilation system, efficiency of heating system, behaviour of occupants, and climatic conditions. All these assumption can only be validated by detailed measurements of the building in operation. There are plans to measure the actual energy performance of the building for verification and future improvement.

Calculations of material emissions: The limited amount of time and information available on quantitites and types of materials to be used resulted in rough estimates for material emissions. A lot of the time was spent on gathering specific data from relevant producers. Producers did not always have information on production related emissions, or they were reluctant to deliver such information, making comparison between materials and products difficult. When we look at the quantities used in the design phase (based on the BIM model), we have quite accurate quantity numbers for e.g. the amount of gypsum plates and insulations materials. However, quantites of concrete in the foundation varied significantly: design phase concrete quantities were 18 m^3, but the actually used amount was 33 m^3. Adding the inventory of the ground foundation and technical installations into a model like BIM could assist in the desing phase emissions calculations.

Figure 4 Rough design phase emission balance, in red are the material emissions, orange are emissions due to the demand for electricity delivered to the building, and the green is the electricity generated from the PV system

One of the goals of a life cycle based ZEB is to reduce emissions through innovative material solutions and design. It can be beneficial to prioritize possible limited resources in the design phase on solutions where significant material emission reductions are likely. By adapting default numbers for standard construction parts (like the outer roof and external walls) or technical instalaltions, one could allocate more resources to the innovative design. When documenting material emissions there is a need for a consistent approach. Specifically to decide the sufficient level of details to be documented. To address this, one could apply a set of rules that allow for consistent simplifications. Random simplifications can reduce the credibility of the concept. From detailed as-built analysis, the most important inputs could be identified and from this, justified simplifications could be determined.

We assumed no changes in emissions from the replaced components and materials. We simply multiplied e.g. PV module emissions with two (30 years*2=60 years). This assumption is conservative, and it is probable that photovoltaic modules produced in 2045 will have higher efficiency and be produced more efficiently with an increased amount of renewable energy [34]. To address this, one could analyse trends within the production industry for key inputs. A simplified approach could be to use multiplication factors based on when the products are assumed replaced. For example in 10 years, a product may be assumed to be produced with 20%

less emissions, in 20 years with 40% less emissions, and in 30 years with 60% less emissions, based on climate policy goals.

Calculations of energy generation: Photovoltaic production yield is dependent on factors like local irradiation, shading, temperatures and efficiencies of inverters and degradiation of the modules. In the design phase, we simulated the energy output from the PV system for one year, with no degradation to resemble the electricity yield for the entire service lifetime of 30 years lifetime. With degradiation, the annual PV yield over a service lifetime of 30 years would have been approximately 13000 kWh instead of 15000 kWh that was calculated in the design phase. On the other hand, we did not assume any increased PV system performance when the PV system would be replaced in 30 years, which is a pessimistic approach.

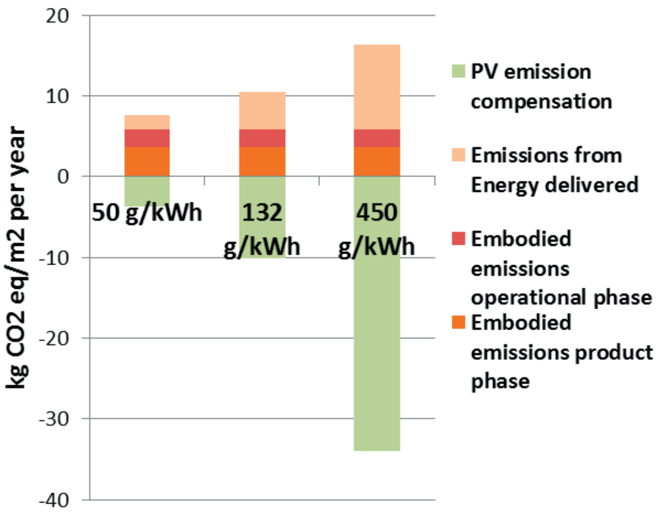

Figure 5 ZEB balance with different electricity emission factors

Balance calculation: In the design phase, a a constant average electricity emissions factor of 132 g CO_2 eq/kWh was used for the ZEB balance calculation. We illustrate the sensitivity of the balance to this choice by calculating balance with two additional factors for the export and import of electricity; a factor of 50 g CO_2 eq /kWh, resembling the current Norwegian emissions and a factor of 450 g CO_2 eq /kWh, resembling current European emissions inspired by [35] [15]. In Figure 5, the ZEB balance with different emission factors is shown. It is more difficult to achieve a ZEB balance with a low emission factor, and easier with a higher factor. Achieving an accurate ZEB balance is a complex task where a dynamic life cycle and CO_2 emission accounting approach could be more appropriate.

4 Discussion

The design phase results indicate that with the applied method and emission reduction efforts, the ambition level of ZEB-OM is nearly achieved. We see from our in retrospect evaluations that our design phase calculations may deviate from the actual performance of the finished building, in particular the dimensioning of the concrete quantities, PV and solar thermal systems. Also, material choices in the design phase were not always specific and details were left out of the emission documentation. However, our future scenario for material replacements was conservative, e.g assuming the same emissions for PV module and window production in 30 years as for the initial emissions. By applying a reduction factor for future material replacements, the total material emissions would have been reduced.

Decreasing the estimated service lifetime will increase the annual emissions. For our life cycle balance we have used a 60 year service lifetime. [36] Suggest a service lifetime of 50 years as the base scenario for life cycle assessments of buildings. There is no general consensus of what service lifetime to use. The data quality for the building materials is expected to be relatively good for the Norwegian building materials, which are based on recent EPD data. For the technical units (such as ventilation and solar thermal system) the data quality is significantly more uncertain.

It is questionable whether a single-family residential house of 200 m^2 of heated floor area is the optimal concept with regards to limiting emissions per person. The current Norwegian residential building market consists of around 52% share of single-family buildings with an average floor area of around 170 m^2 [37]. A functional unit looking into emissions per person could be used as an additional functional unit. According to [4] all ZEB buildings should be monitored and compared to designed and simulated performance, emphasising the need for as-built performance evaluation.

5 Conclusion

With several design phase efforts to reduce and compensate emissions, a zero emission balance was nearly met for our case study building. Our approach is sensitive to methodology for material emission accounting and the choice of electricity emission factor for the import and export of electricity. Our evaluation of the design phase method shows that extracting quantities from a BIM model can increase accuracy of design phase material emission calculations. We recommend that design phase efforts on material emissions should be focused on selected areas where significant emissions reductions from material use are possible. In general, we show the need for a methodology for the design phase of ZEBs that includes simple and solid rules for allowed simplifications, service lifetimes and future scenarios. To perform as-built analyses to verify the actual buildings performance would be interesting further work.

6 Acknowledgements

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Designing and retrofitting the urban structure with daylight

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Summary

According to the UN report, the urban population will nearly double in 2050. The rapid demographic change and the increasing urbanization cause new spatial and social framework conditions for urban planning. Daylighting masterplans provide an opportunity to tackle the lack of urban space with sophisticated architectural concepts based on in-context and human-centered solutions. This method offers a large-scale approach to coordinate the design and/or retrofit of new and existing neighborhoods. In order to obtain human-centered solutions, biological, psychological and physiological needs of the citizens need to be considered in addition to the typical energy optimization. An analysis of performance criteria indicated that colorimetric characteristics play an essential role in this. The work presented in this paper aims at developing a computer-based parametric tool to optimize the daylight planning for multiple buildings based on spectral sky models. This tool allows a better impact assessment of designing urban spaces with daylight by outlining the dynamic range of daylight, specifically for non-visual effects of the light. The tool builds upon the spectral data measurements carried out by the Technische Universität Berlin (TUB). It enables to translate the spectral data into a spatial design software. The main emphasis thereby is the practical applicability of the sky models in an urban planning process. The outcomes of this work will support the design of sustainable built environments.

Keywords: daylight master plan, sustainable urban planning, daylight design, spectral sky models, smart cities

1. Introduction

Today's cities are subject to dynamic spatial and social change. According to the United Nation's estimates, the urban population will increase dramatically in the next years. The rapid demographic change and the increasing global urbanization cause new framework conditions for urban planning. To minimize the environmental burden and to improve the quality of life in the more and more dense city texture we need to build in a sustainable, durable and reasonable way. Daylighting master plans provide an opportunity to tackle the lack of space with sophisticated architectural concepts and with in-context human-centered solutions. This urban design method offers a large-scale approach to coordinate the design and/or retrofit of new and existing neighborhoods based on natural light conditions.

Up to date, in the consideration of daylighting master planning as a sustainable urban design strategy, energy optimization is typically the only guideline and main purpose. The analysis of additional performance criteria and related design parameters was carried out in a two-step process within this research project. In the 1st step relevant criteria and parameters were determined by searching literature databases: Web of Science and Google Scholar. The practical relevance of the selected parameters and criteria was then verified with nine case studies. The selected performance criteria were:

- visual aspects,
- non-visual aspects,
- glare, and
- energy performance.

Based on the literature survey following design parameters were identified as relevant in the urban planning with daylight:

- location,
- sky type (prevalent sky conditions),
- façade form and coating,
- façade orientation,
- surroundings.

The case studies analysis has proved the relevance of the parameters and performance criteria but has showed that most parameters are considered however rarely all the performance criteria are looked into simultaneously. The literature survey and case studies analysis gives an essential basis for the development of a model to outline the dependence between the parameters and the criteria and the interdependence between the criteria (Figure 1).

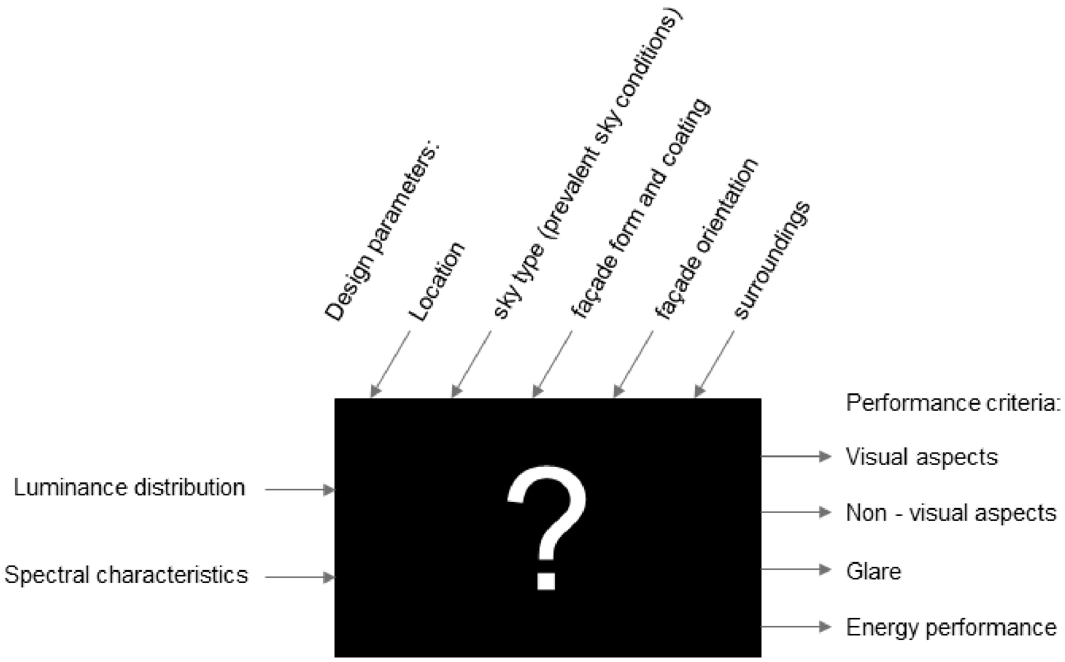

Fig. 1: A model to outline the dependence between the photometric quantities, the design parameters and the performance criteria

Specifically considering biological, psychological and physiological needs of the citizens, the literature survey and case studies indicated that colorimetric characteristics play an essential role in the human centered performance criteria. Hence the need to factor in the spectral information of daylight, next to the illuminance level and the emphasis on the interdependence between the performance criteria, in order to realize healthy and sustainable urban environments.

2. Methodology to create spectral sky models

This research aims at developing a computer based parametric tool to optimize the daylight planning in urban structures for multiple buildings based on spectral sky models. The inclusion of the colorimetric information supports the consideration of non-visual aspects in daylighting design. This research is meant to support the design of sustainable daylighting master plans for cities, by defining the colorimetric characterization of daylight in the urban structures and subsequently assessing the impact of daylight on non-visual aspects in urban settings (Figure 2). The main emphasis thereby is the practical applicability of the sky models in an urban planning process.

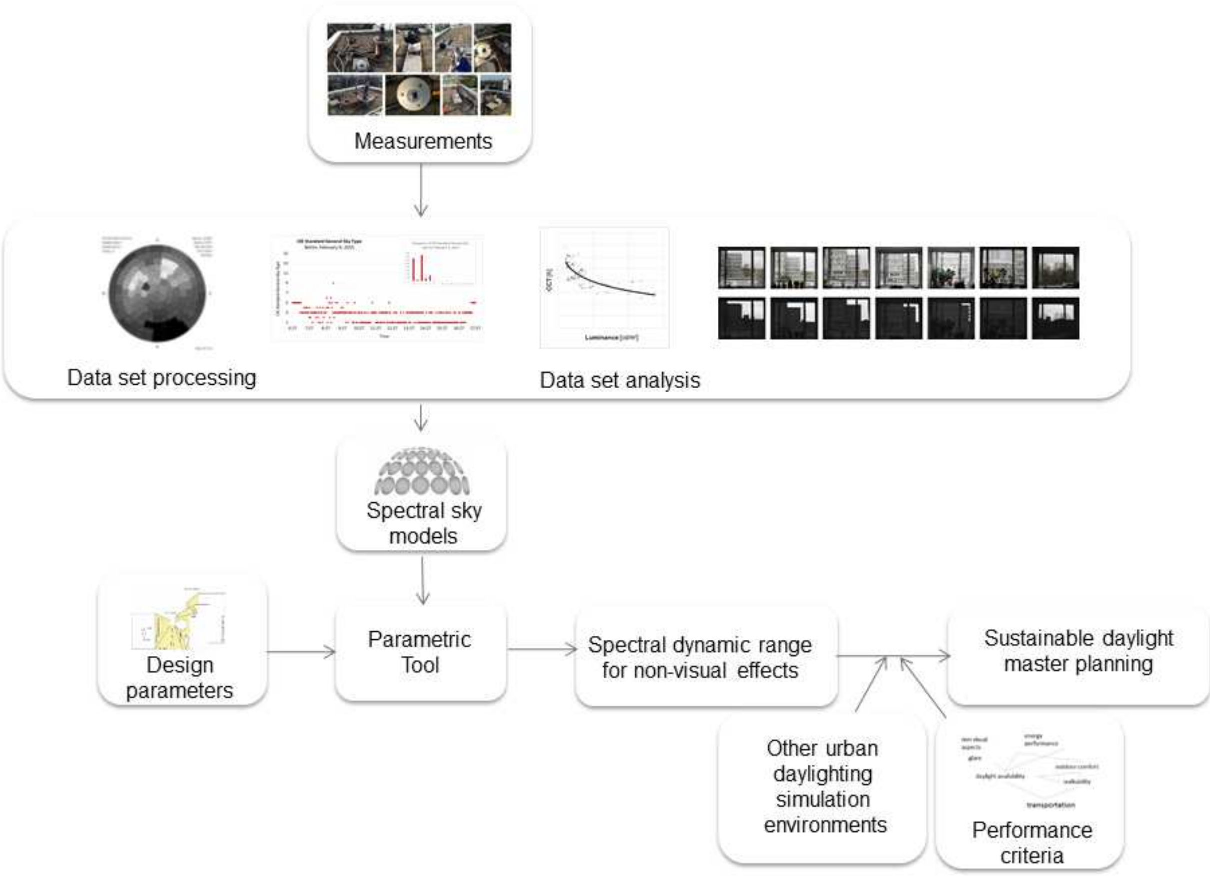

Fig. 2: Operationalization diagram for research on daylighting master plans (Diakite 2015)

Spatially resolved spectral power distribution measurements of daylight are carried out at the TU Berlin since October 2014. Every 2nd minute, the spectral power distribution beween 280 and 980 nm is measured for 145 sky patches according to Tregenza with a spectral sky scanner of Czibula & Grundmann (Knoop et al. 2015). (Figure 3) The aim was to create a calculation model to determine the correlated colour temperature distribution for various sky types analogically to the luminance sky distribution. This study investigates whether spatially resolved spectral light distribution can be described equally to the Standard Sky Luminance Distributions in accordance with ISO / CIE standard (CIE 2003). The sky types are determined according to Kobav et al. (2013).

According to Chain et al. (2003) correlated colour temperature (CCT) of a specific sky patch corresponds to the sky patch's luminance. This relation between the CCT and the luminance differs depending on the CIE sky type. The spatially resolved spectral power distribution measurements generated at the TU Berlin allow to verify the interdependence between the luminance and the CCT of a sky patch being subject to prevalent sky conditions. In analogy to the visualization of the luminance data according to Kobav et al. (2013), software for graphic representation of the spectral data has been developed. Subsequently it should be verified whether the colorimetric distribution from sky types can be derived from the sky luminance, the clarity and brightness of the sky (Chain 2004). These distribution models of the colorimetric characteristics enable the implementation of the spectral information in simulations.

Fig. 3: Sky scanner at the daylighting measuring site at The Technische Universität Berlin

3. Results

Based on the spatially resolved spectral power distribution measurements the luminance, sky type, chromaticity coordinates and the CCT can be determined. To automate the analysis of the data a software has been developed (Figure 4). This tool enables the determination of the gradation and indicatrix group and this subsequently allows to define the sky type according to Kobav et al. (2013). Furthermore it allows the graphic representation of the colorimetric characteristics and the luminance distribution.

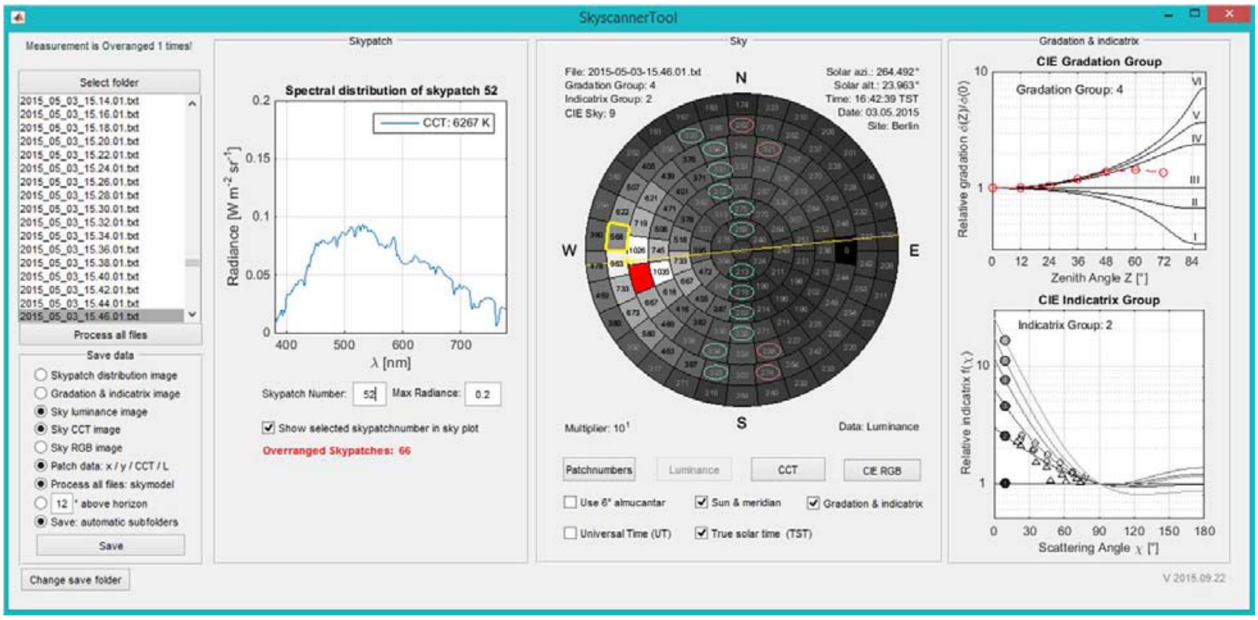

Fig. 4: Software for graphical evaluation of the measured data and determination of the sky type

The chromaticity coordinates of each sky patch can be defined from the spectral power distribution. CCT is calculated with the Robertson method (1968). (Figure 5) The spectral power distribution can be displayed for all 145 sky patches.

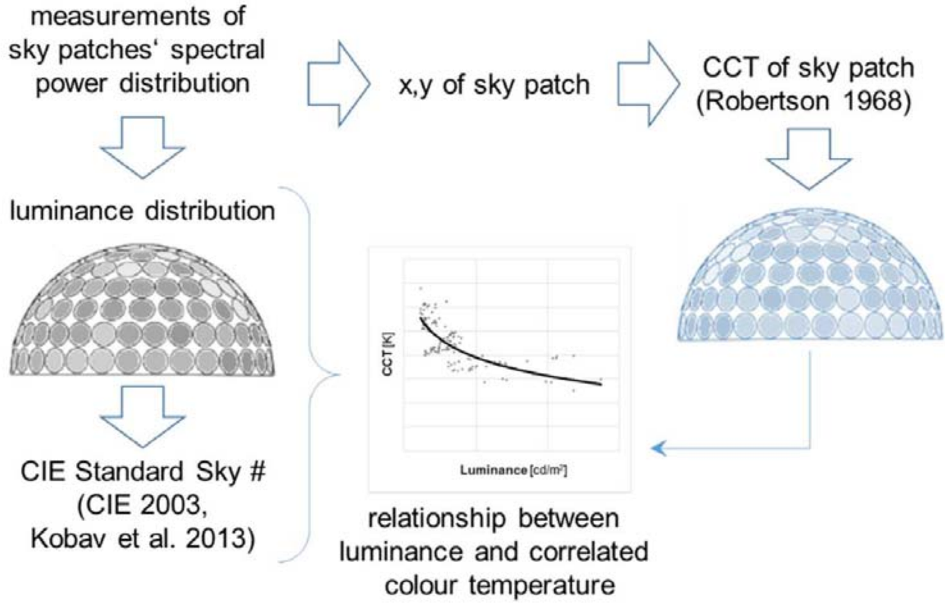

Fig. 5: Methodology to create spectral sky models (Knoop et al. 2015)

Furthermore additional software was develop to determine the dominant CIE sky type for Berlin. As the measurements to obtain datasets for the whole year were accomplished in October 2015, research is ongoing to determine the dominant CIE sky types for Berlin for each month (Figure 6) and to verify if there is a relationship between sky patch luminance and CCT.

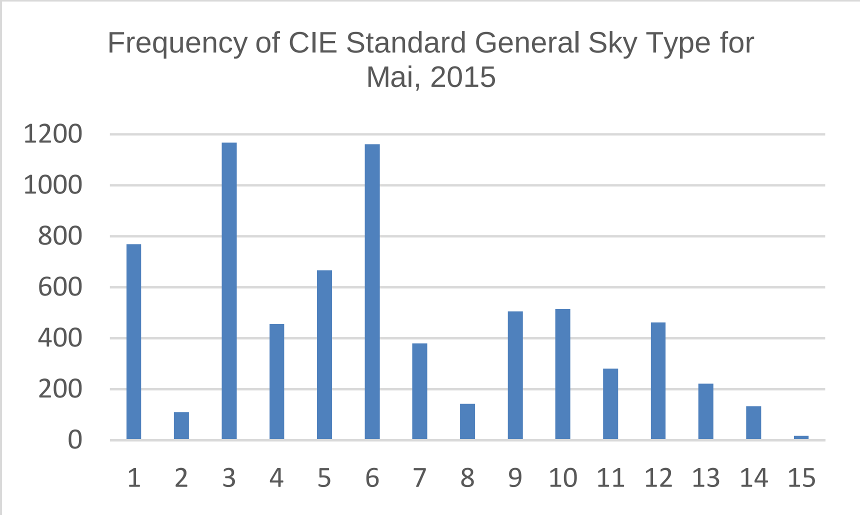

Fig. 6: Frequency of CIE Standard General Sky Type for Mai 2015

4. Discussion

4.1 Practical applicability of spectral sky models in simulations

The measured data set needs to be further examined. The spectral model is then to be tested against theoretical assumptions. In following should be examined whether a simplification of the spectral sky models is possible. In order to define what percentage of the view falls within a given sky patch the influence of the spectral information of an individual sky patches on the general daylight conditions in buildings need to be identified (Figure 7). Furthermore a sensitivity analysis regarding urban form parameters should be carried out to determine how much does a spectral sky model affect certain simulation based performance target i.e. non-visual effects. In the framework of the sensitivity analysis the new spectral sky model could be used as a “proof of concept” to test or demonstrate its value to specific questions (e.g. health, circadian rhythm, visual/non-visual effect).

Fig. 7: Determination of the influence of the spectral information of an individual sky patches on the general daylight conditions in buildings

4.2 Simplification and priority-setting of parameters for simulation

The literature review indicated the importance of sky type, location, façade form and coating, façade orientation and surroundings in the daylighting masterplanning (Figure 8). In order to define which design parameters drive performance and to prioritize the parameter, a parameter study with scale models is planned. The scale model study allows to modify certain parameters under controlled conditions and to identify the contribution of each parameter to the performance. This study will be carried out in December 2015.

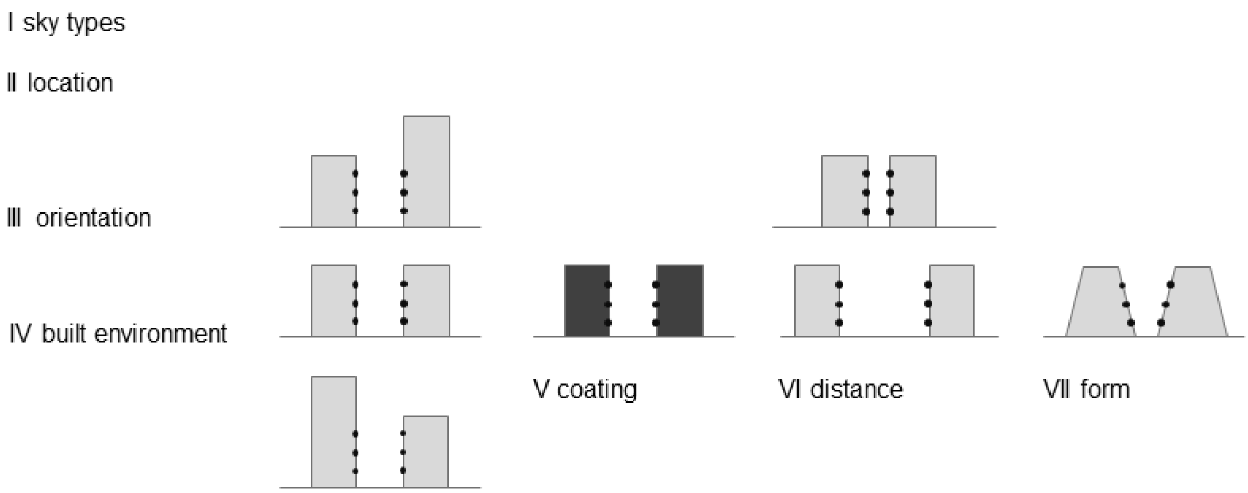

Fig. 8: Scale model study to evaluate the influence of the design parameters on planning inside a street canyon with daylight

5. Conclusion

This research will be concluded with the parametric tool to optimize the daylight planning in urban structures for multiple buildings. The implementation of the colorimetric information supports the inclusion of non-visual aspects in daylighting design. The tool will serve as decision aid for the authorities, as information platform for the citizens, as persuasion tool for investors and as planning device for the planners.

6. Acknowledgements

The presented work is part of the project “Environmental and ergonomic optimization of new lighting solutions for retrofitting and new construction of buildings” (03ET1148B) funded by the Federal Ministry of Economics and Technology (BMWi). The authors would like to thank Frederic Rudawski, Adrian Schödl and Song Gao for their contribution to the research.

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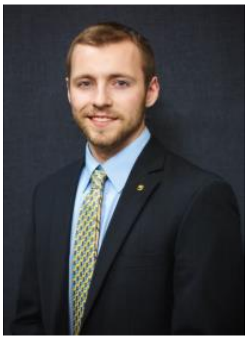
Determining Characteristics in Developing Economies that Influence Sustainable Construction



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Summary

Sustainability is an interdisciplinary topic with implications in a variety of areas such as manufacturing, automotive industry, politics, and the built environment. This research explores the degree sustainability has been implemented in the built environment of countries with developing economies and investigates potential factors that correlate with the level of implementation. For this research, authors focused on correlations among sustainability in the built environment in a developing economy and the percentage of labor, environmental health and GDP per capita. Results indicate moderate to strong correlations among the aforementioned factors and the level of sustainability integration in the built environment within developing economies.

Keywords: Sustainable Construction, Developing Economies, Labor, Environmental Health, GDP

1. Introduction

Organizations such as the United States Green Building Council (USGBC) have developed systems for assessment and certification of buildings in order to provide guidance and recognition in the sustainable building industry. The most widely used building assessment system around the world is the one developed by the USGBC called Leadership in Energy and Environmental Design (LEED) system. As of August 2015, based on the USGBC website, there are currently more than 72,500 LEED building projects located in over 150 countries and territories. Using assessment systems like LEED, researchers can explore correlations with various characteristics in an attempt to understand how sustainable construction grows within developing economies.

2. Methodology

Authors started the research with the CIA World Factbook to create a preliminary list of developing economies. Using LEED as a benchmark measure for sustainable construction, a number of developing economies worldwide were analyzed in which LEED is the predominant sustainable building rating system. Authors specifically focused on those countries in which a minimum of 75 percent of all sustainable building rating system activity involve LEED and with a minimum of three certified buildings. Once these criteria were taken into account, LEED certified square feet per capita (LEED SF/Capita) of 26 countries with developing economies were introduced into the analysis. This value is calculated by dividing the total square feet of certified LEED buildings in a country by the country's total population. Authors used LEED SF/Capita as the dependent variable to represent sustainability in the built environment against dynamic independent variables.

In order to determine the independent variables with potential impact, authors conducted an extensive literature review on sustainable construction and developing economies in three main areas: Social Structure, Economic Health and Environmental Status. Using specific country data extracted from the CIA Factbook and the Environmental Performance Index developed by Yale and Columbia Univerisities, authors created a spreadsheet database for organization and interpretation of trends within the selected countries. Authors ran pair-wise correlation analyses within Excel and SPSS to determine statistically significant relations.

3. Results and Conclusion

Results show three significant correlations with the LEED SF/Capita value: Percentage of Labor $r(73) = .326$, $p < .01$, Environmental Health $r(73) = .474$, $p < .01$, and GDP per capita $r(73) = .802$, $p < .01$. Percentage of Labor is a percentage of working population, and includes Agriculture, Industrial and Services. Environmental Health is a calculated value in the 2010 EPI Data Sheet measuring Environmental Burden of Disease, Air Pollution effects on humans and Water effects on humans. GDP per capita is a calculated value found by dividing a country's GDP by the total population.

Results of this study illustrate moderate to strong connections among sustainability in the built environment and the amount of labor available in a country, the environmental vitality, and the average wealth. These correlations do not necessarily prove causation, but simply prove there is a connection. Results of this research can be used to better understand sustainable construction trends in developing economies. Further research could include developing specific measures of sustainable construction, expanding the sample countries and utilizing other green building certification systems that are dominant in other countries. Authors are currently working on developing a comprehensive index called Green Building Accessibility Index to better assess sustainabilty in the built environment within various countries.

Developing Abu Dhabi's Sustainability Energy Index

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Summary

According to figures for the year 2011, Abu Dhabi's energy consumption was the highest globally. The consumption figure is expected to increase sharply. The two segments that increased this consumption are domestic power and transportation fuel. Fast population growth, unique weather, gross floor area and high energy subsidies are the main driver of high energy consumption. Abu Dhabi is committed to generate 7% of its total energy from renewable sources and 26% from nuclear energy by 2020. It is unlikely, with the current pattern of consumption, that Abu Dhabi will be able to achieve its target. This paper aims to develop a set of sustainability indicators for the unique and challenging Abu Dhabi environment. The anticipated framework has 21 indicators that have been categorised into 6 segments; namely, energy utilisation, energy effectiveness, environmental safeguards, monetary sustenance, policy making and administration. A consolidated cause-effect method, DSR, was used to interrelate the indicators. This index is structured around the DSR approach, where the driving force is related to energy consumption. The evidence of climate change as a result of CO2 emissions represents the state of which a response from government policies is expected. The analysis of the proposed energy indicators intended to help decision makers in assessing the performance of the city, and the values of the indicators over time highlight the city trend towards sustainability.

Keywords: Sustainable development, indicators, Energy, DSR

1. Introduction

Energy is a key contributing theme in the city and an important issue in achieving a sustainable built environment. The world's energy demand has increased at an average rate of 2 % each year [1]; as a result, the CO2 emissions and global warming have increased, and most of present patterns of energy supply and use are unsustainable [2]. Agenda 21 was the main outcome of the Rio conference in1992: Chapter 9: 'Protection of the Atmosphere' states in regard to energy that it is: Produced and consumed in ways that could not be sustained if technology were to remain constant and if overall quantities were to increase substantially. The need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be based on efficiency in energy production, transmission, distribution and consumption, and on growing reliance on environmentally sound energy systems, particularly new and renewable sources of energy [3].

2. Methodology

This study examines the sustainability performance of Abu Dhabi Emirate, the capital of the UAE. As of 2011, it had a population of 2,120,800, and occupied an area of 67,340 km² [4]. Driving force- State- Response(DSR)framework for energy is where the driving force is related to energy consumption. The evidence of climate change as a result of CO2 emissions represents the state, of which a response from government policies is expected. Validation of the selected indicators and their assigned weight was made using the Delphi technique. The key objective of this technique is to obtain consensus information from different stakeholders. The involvement of stakeholders is a key part of developing of a strong decision making framework. The weights were assigned to all sustainability indicators using pair-wise comparison; the importance of each indicator was taken from stakeholder's evaluation of indicators. Based on this information, a numerical score for Abu Dhabi's sustainability performance was assigned, Figure 1 shows the overview of the methodology process .

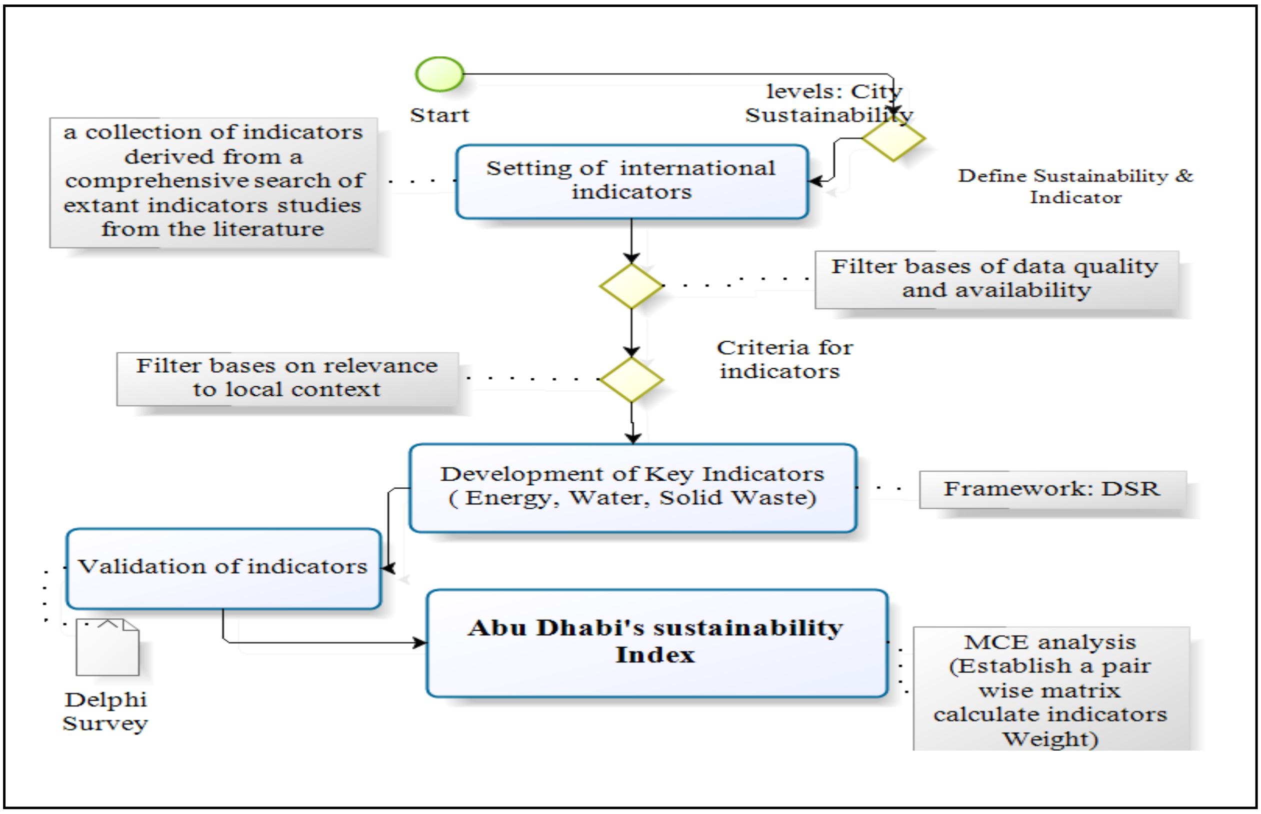

Fig. 2 Overview of the methodology process

3. Interpretation of the Results

Abu Dhabi's Energy sustainability index was developed based on understanding Abu Dhabi's needs and priorities. as shown in Table 1. The anticipated framework has 21 indicators that have been categorised into six segments; namely, energy utilisation, energy effectiveness, environmental safeguards, monetary sustenance, policy making and administration.

Table 1: Abu Dhabi's energy sustainability index

No	Sustainability Indicators	DSR	Scale		AD Data	Score	Weight	Final Score	Spatia	Ref
			Max	Min					√ x	
	Accessibility									
1	Population with access to electricity (%)	S	100%		100%	100	0.021	2.132	√	[6]
	Energy Use & Efficiency									
2	Total energy use per capita (Kgoe/cap)	D	3,000	1,800	11,103	0	0.065	0.00	√	[6], [5], [7]; [8]
3	Electricity consumption Kwh/cap	D	10,22 7	2,974	20,390	0	0.065	0.00	√	[5] [9]
4	Identification of the stream of electricity consumption (residential, industrial, agricultural, commercial/services)	S	World Avg: Household 28% Commercial 8%		House. 30.1%, Comm28.8%, Gov 25.1%, Agr 7%, Industry 8%	100	0.065	6.528	√	[5], [10], [11]
5	Disparities: "*household energy use for each income group and by dwelling type (Household/kWh/ year)*"	D	3,471		Expats (Flats 7,200-12,400, Villas 32,100-97,000), Nationals (Flats 12000, Villas 93,000-97,000)	0	0.021	0.00	√	[12], [13]
6	The share of energy consumption *"in transportation sector per total final energy consumption"*	S	26	20	27	0	0.014	0.00		[5], [6], [14]
7	Grid efficiency*: "% Electricity transmission and distribution losses"*	S	5.9		5.9	100	0.065	6.528	√	[9]
8	Safety: *"number of annual fatalities per energy produced by fuel chain"*	S		0	18	18	0.021	0.384	x	[5]. [6]
9	Diversification (fuel Mix): *"fuel shares in energy and electricity"*	S	10	0	natural gas 96%, Crude Gas& Oil 4%	1	0.036	0.036	x	[5]. [6]
10	Renewable Energy: *"energy used from renewable source such as a percentage of total energy consumption"*	S/R	-	20	0% target 7% in 2020	0	0.065	0.00	√	[5], [6], [8]

11	Energy intensity: *“total annual energy consumed by the city, in per unit of GDP (US$)”*	D	154.9		135.5	100	0.065	6.528	x	[6]
12	End use: *“household electricity Intensities (kWh/cap)”*	D	731		7,207	0	0.036	0.00	√	[5], [12]
13	End use: *“transport energy Intensities (toe /passenger/km)”*	D	2.3		2.5	0	0.021	0.00	√	[6],[15]
	Environment Protection									
14	Climate change: *“carbon dioxide emission from energy activities (tonnes /cap)”*	S	10.1	4.7	26.2	0	0.110	0.00	√	[6]; [5]
15	Air Pollution*: “emission from energy industries (KT/y)”*	S	SOx: 30 NOx: 50		SO2x=210, NOx= 79	0	0.065	0	√	[5], [6], [16]
16	Water pollution: *“contaminant discharge in liquid effluents from energy families(T/y)”*	S	0			0	0.065	0.00	√	[5]. [6]
17	Solid waste: *“ratio of solid waste generation to units of energy produced (kg/toe)”*	S	5	3	2.65	74	0.036	2.692	x	[6], [5], [17]
	Financial sustainability & Affordability									
18	Affordability: *“household energy Expenditure Load % (energy expenditure/average household income)”*	S	100	0	10	10	0.021	0.213	x	[5]. [6]
19	Energy price: *“average price in US$ for electricity kWh and fuel L of regular gasoline”*	S/R	0.16, 1.91	0.82, 1.4	Res =0.0082, Ind=0.0409 fuel0.47	0	0.036	0.00	x	[6]
	Governance & Policy									
20	Clean and efficient energy policies: *“an assessment of the extensiveness of policies promoting the use of clean & efficient energy”*	R	100	0	40	40	0.065	2.611	x	[18]
21	Public participation: *“measure of the public engagement in activities of clean and efficient energy use”*	R	100	0	20	20	0.036	0.727	x	[18]

Each indicator's score are provided in more detail in the following sections:

Share of population with access to electricity (%). The indicator shows that 100 % of the population has access to the electricity. Abu Dhabi Emirate is a highly developed city; like other high income cities, electricity accessibility is 100 %, with an excellent electricity network that has almost no power outages.

Electricity consumption per capita. The electricity consumption in Abu Dhabi Emirate also scored a poor performance. It has increased, and this raises concerns about its pressure on the environment, as well energy security in the area, due to limits in terms of the country's natural gas reserves. EAD (2010) points out that the increase in electricity consumption is due the rapid growth of population, together with the increased average consumption, and the expansion of inter-Emirate export market involving Dubai and the Abu Dhabi. However, the electricity consumption per capita in Abu Dhabi Emirate is one of the highest levels in the world, almost twice the OECD average and more than 6 times higher than global average. According to the World Fact Book, the UAE was rated in seventh place [20], while if we compare Abu Dhabi Emirate, it was the third highest world consumer, with more than 20, 00 kWh per capita.

Stream of city electricity consumption. In Abu Dhabi, the household sector is the largest electricity consumption stream, with a share of 39 % of total electricity consumption by the city, while the commercial is second at 31 %, government consumption is 17 %, and the agriculture sector consumption is 9 % [5]. Accordingly, the major stream of electricity consumption in Abu Dhabi Emirate are the household and commercial sectors, and necessary action must be taken by the decision maker in the area.

Disparities (household electricity consumption for each income group). Abu Dhabi has one of the most diverse populations in the Middle East and North Africa area [20] [21]. Based on 2010 statistics, 73 % of the population are expatriates and 22 % are national citizens. There is a big disparity among family income, property and energy consumption in Abu Dhabi Emirate. In terms of property and residential status, Abu Dhabi's nationals residing in villas consume the highest amount of power, between 93,000 kWh and 97, 00 kWh. Those living in Shabiyat (houses built by government) consumed between 69,000 and 80,000 kWh. On the other hand, non-citizens living in villas consumed between 32,100 and 97,000 kWh, while those in apartments recorded between 7,200 and 12,400 kWh in consumption. It might seem that the heavy subsidies negative impact on locals and Expats behaviour, more subsidies lead to unsustainable behaviour. Furthermore, residents live in villas consumes more energy than those live in flats; It seems that the type of house effect on residents' consumption amount of energy

Share of transport sector. This indicator measures the share of energy consumption in the transportation sector per total final energy consumption In Emirate, the estimate amount shows at about 27 %, while the threshold value is 20 to 26 %.

Grid efficiency. Percentage of electricity transmission and distribution losses. The electricity grid in UAE (as well in Abu Dhabi) is highly efficient, and the estimated percentage of losses in electricity transmission and distribution decrease was 5.9 % in 2010, while according to The World Bank statistics, the OECD average was 5.92 %, with Netherlands at 3.7, USA at 5.9 and Australia at 6.1 in the same year.

Diversification (fuel mix). Abu Dhabi Emirate is largely dependent on natural gas as the fuel for water and electricity production, and this contributed an average of 96 % of the total of annual electrical energy produced in 2011. The electricity demand has increased in Abu Dhabi Emirate, due to increases in population and changes in lifestyle and this is expected to increase in the coming year. The production of electricity is mainly from natural gas imported from other countries, which raises concerns about energy security in the city. However, natural gas is more preferable from an environmental perspective than other fossil fuel sources, the decision-makers must seek to diversify its energy sources. Comparison of Abu Dhabi's fuel consumption in electricity activities to other countries raises a concern. According to World Bank report (2013), the OECD generated 10.15 % of power from sources that are inexhaustible (excluding hydroelectric) and 51.9 % from natural resources.

Safety. Measuring the number of annual fatalities per energy produced is an important factor to assess human safety in the cities. In Abu Dhabi Emirate, according to the Statistic Centre (2012), the number of fatalities from electricity activities in Abu Dhabi Emirate decreased from six fatality incidents in 2010 to zero in 2011, while the incidence of fatality increased in the oil and gas sector to 18 fatalities in 2011, compared to four in 2010. The main reason for that was increasing working hours in oil and gas companies in 2011, of 65.8 % compared with 2010 [5].

Renewable Energy. Abu Dhabi scored a poor performance in using renewable energy. According to the Abu Dhabi Statistic Centre in 2010, electricity production from solar energy reached about 17,239 MWH; this is an extremely small amount compared to city electricity consumption. However, 26 % of this amount was consumed in Masder city, while 74 % was transmitted to the distribution network in Abu Dhabi Emirate [5]. Future expectations on the role of renewable energy are very high, Abu Dhabi is supposed to produce 7% of its overall energy from renewable sources [5]. Abu Dhabi facing a serious challenge in using solar and wind energy. Abu Dhabi is located in a desert environment with high level of dust and less amount of wind. the high dust level affect negatively in PV performance with only a possibility of using 15% of total capacity, less opportunity should be expected of Abu Dhabi's renewable energy. Fossil fuels might remain the leading supplier of energy in Abu Dhabi for a long term.

Energy intensity. This indicator measure total annual primary energy consumed by the city in US$/kg of oil equivalent per unit of GDP. Abu Dhabi scored a poor performance in this indicator, this is mainly due to high GDP per capita.; Abu Dhabi is the wealthiest city in the area in terms of GDP per capita income. The GDP per capita ranked Abu Dhabi Emirate as ninth highest in the world in 2010. GDP reached 219,627 million US$ (1US$= 3.67 AED) in 2011, compared with city energy consumption in the same year, which reached to 24,198 thousand toe (the energy intensity 110.18 kg of oil equivalent) per $1,000 GDP.

Household electricity intensities. Abu Dhabi scored a poor performance in this indicator and was well below the threshold value. Owing to excessive power consumption at the domestic front, the Emirate has a great energy requirement; power consumption in the Emirate is seven times the global average consumption. Household electricity consumption is one of the highest in the world. Per capita, Abu Dhabi households consume about 7,207Kwh, while the world average for household electricity consumption stood at 731Kwh/ capita in 2010 [12].

This indicator shows policymakers pressure on energy resources, the proposed indicator is intended to assist decision-makers in their adoption, either through more efficient use of current resources or through highly targeted new issues. The electricity consumption in Abu Dhabi is extremely high, despite all the justifications, the residents are consuming more than their essential need. As mentioned earlier, hard efforts should be gathered to work towards changing the household sector behaviour in the consumption pattern. Changing individual behaviour is a difficult process [23]. The policy and regulatory context is a critical issue in the public behaviour change in relevance to energy consumption pattern. Decision makers need to have effective policies and related legislations enforced by law.

Transport energy intensities. As transportation is one of the major energy consumption in the cities, it is important to assess energy consumption in this sector. Measuring transport intensities is a difficult task; this is due to different types of transports used in the cities. Energy intensities depend on the type of the transportation such as cars, trucks…etc, it also depends on the road network, if it is a highway or narrow way. Based on that, the intensity of light duty vehicle was chosen to measure the transportation energy intensity.). The energy intensity of cars for UK and France is about 2.3 MJ/Km while in Abu Dhabi city it has been estimated based on 2009 data 2.5 MJ/Km.

Climate change and carbon dioxide CO2 emissions. CO2 emissions and climate change from energy use affect the security of Abu Dhabi Emirate. CO2 emissions reached to 26.7 tonnes/capita and 26.2 in 2009, these numbers were more than double the average of the OECD and well above the threshold maximum value. According to World Bank statistics, in Singapore CO2 emissions reached 6.4 in 2009, while in Sweden, Netherlands, USA, Australia and Luxembourg they reached 4.7, 10.3, 17.3, 18.4 and 20.4 respectively in the same year. Energy use and electricity production is a main source of carbon dioxide emissions in Abu Dhabi. CO2 related to power production and consumption indicates that there has been an annual increase of six million tonnes every year since 1990 [13]. By 2004, the emissions reached a maximum level of 17.9 million tonnes, decreasing a bit in the subsequent year, registering 17.6 million tonnes. Based on the population figures released in 2005, this amounts to 11.9 tonnes of carbon dioxide gas per capita released, due to the public power generation [13]. However, there has been a marked decrease as far as the per capita CO2 emissions are concerned; from 2006 until 2010 [5].

Air Pollution. Air pollution from both electricity production and the oil and gas sector in Abu Dhabi fluctuated, The total emissions increased slightly in 2011 and reached 28,900 tonnes. according to Statistics Centre in Abu Dhabi (2012), the emission of sulphur dioxide (SOx) reached 210,000 tonnes and nitrogen oxides (NOx) reached 79,600 tonnes, which is significantly high in comparison to the threshold value.

Water pollution. This indicator measures the contaminant discharges in liquid effluents from energy systems, including oil discharges. Abu Dhabi had four power stations, all of them located on the coastal area, the sea water is used for cooling purposes and allows more efficient and less expensive power generation [13]. Although the Emirate faces a major scarcity of freshwater, large amounts are required, mainly in electricity production and cooling systems, which rely on gas-fired power plants; water is drawn from the Gulf Sea but is desalinated before being used in the process [13]. One of the main sources of sea water pollution is oil. Abu Dhabi's coast is also the location of oil and gas extraction activities and the associated supporting infrastructure, such as refineries, pipelines and shipping terminals [13].

Solid waste. Despite the limitation of available data about solid waste generation from the oil sector in Abu Dhabi Emirate, significant amounts of hazardous waste from oil operations are in storage at Ruwais landfill [13] [24]. Elshorbagy and Alkamali (2005) studied the solid waste generation from the oil and gas sector in specific oil fields in Abu Dhabi. The outcome from this study shows that the annual solid waste generaed was 40611 tonnes, which is equivalent to 650 kg/

capita, 0.371 kg/ barrel oil and 1.58 kg/m3 of extracted gas. This is smaller than the international agreement amount with range of 3–5 kg per tonne of crude [17]. The estimate of waste generated from energy activities is around 2.65 kg per tonne. This is mainly due to good quality of oil in the area.

End-use energy prices. The power tariff rate in Abu Dhabi is among the lowest in the world. As a result, power usage is unjustified and there is a lot of wastage. Residents in Abu Dhabi Emirate benefit from electricity subsidies, local residents pay only 20% and expat residents pay 60% of the actual bills [25]. It became apparent that the heavy subsidies influence negatively on residents' behaviour, in the face of extremely high consumption, decision makers should strive to enforce the sustainable behaviour. There's an urgent need to remove the heavy energy subsidies.

Household energy expenditure load . All residents in Abu Dhabi benefit from high government electricity subsidies, with the average annual household income varing according to nationality [20]. Annual bills indicate distinct overlaps; resident expatriates in Abu Dhabi living in apartments pay an average annual bill of between 1,100 AED and 1,850. Those living in villas, on the other hand, pay between 4,800 AED and 14,650 AED. UAE nationals living in villas pay an annual figure ranging from between 4,650 AED and 4,850 AED, while others living in Shabiyat pay an annual bill of between 3,450 AED and 4,000 AED [26]. Of national citizen families, 41.8 % live in Shabiyat and 67.9 % of expatriate families live in apartments. The average annual national citizen income per household is US$ 152,918 compared to the expatriate average annual income per household of US$ 48,648. Expenditure electricity load for national citizen families who live in Shabiyat is about 0.39 %, and expatriate families who live in apartments about 0.79 %.

Clean and efficient energy policies. Measuring government policy and legislation on clean and efficient energy is an important indicator. Clean and efficient energy policies have been measured and scored. This method has also been used by [27]. The total items with a positive answer are two out of four; the final score is 40 out of 100. Policy makers have been long aware of energy used inefficiently, and they are struggling to increase the capacity of energy generation. Policy makers must put more effort into reviewing the Emirate's energy demand and consumer behaviour; further examination of current consumption practices can help determine the root of the problem, and missing clear efficient energy policies might be the main driver of high energy consumption; moreover, there are high electricity subsidies and cheap fuel prices.

Public participation. In Abu Dhabi there is no clear policy to involve the public in energy policy. To measure public participation, key criteria has been proposed. The total items with positive answers are one out of five; the final score is 20 out of 100. Awareness campaigns are a key factor in public awareness to know the risks and/or benefits of particular behaviours. There are no comprehensive campaigns to target public energy use efficiency in Abu Dhabi Emirate. One of good campaign was 'Heroes of the UAE', which aimed at Abu Dhabi residents reducing their carbon footprint by offering minor changes in everyday practices that reduced electricity and water consumption [13]. This kind of campaign needs to be constant, and to target all different groups of the community.

4. Conclusion

Achieving sustainability has become a vision for the Abu Dhabi government; nevertheless, without strong strategies this can be extremely difficult. It is vital that Abu Dhabi Emirate learns from

other cities and benefits from global best practice. This can help the city to compare and control its natural resources towards sustainability and to keep the environment protected for future generations.
The focus of this study was on developing unique sustainability indicators for Abu Dhabi's built environment. The lack of quality and accurate data has proved a major limitation to the process of developing Abu Dhabi sustainability indicators.

From this study it is found that, the Abu Dhabi has low sustainability performance, comparing with the average global sustainability performance. To address Abu Dhabi's low sustainability performance a close coordination between the stakeholders during formulating environment polices is much needed. In order to enforce these polices each entity should have defined roles and responsibilities. Enforcement of legislation at all levels will significantly change the residents behaviour and will help the city to achieve better sustainability performance in the future.

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Developing the Brighton Waste House: from zero waste on site to re-use of waste

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Summary

In 2014 the author completed Europe's 1st permanent public building made of (approximately) 90% material discarded by others. Known as the 'Brighton Waste House' [i] it was designed and built by over 360 students, apprentices and volunteers. It also has full Planning and crucially UK Building Regulations Approval. However, it was initially going to be a completely different project. It was originally conceived as the re-build of 'The House that Kevin Built' from 2008.[ii]

Frustrated with the lack of knowledge, and indeed interest, around issues of sustainable design within the UK construction industry, the author was keen to create a 'live' teaching project that included young learners, practitioners, educators, contractors and suppliers in the process of design and construction. The premise being that if the challenge was to deliver a truly innovative building, and that if the 'innovation' in question addressed on some of the many issues under the umbrella title of 'Sustainable Design', then a greater understanding, of said issues, across practices within the design and construction industry, would perhaps be attained.

Keywords: Re-use, sustainable materials, collaborative learning

1. Introduction

1.1 Themes influencing the research.

1.1.1 The UK generated 200 million tonnes of waste in 2012. 50% of this was generated by construction. Commercial & Industrial activities generated 24%, with households responsible for a further 14%. [iii]

1.1.2 Approximately 20% of all material arriving on building sites ends up incinerated or going to landfill and 30% of this is new material never used. Finding ways to reduce or eliminate waste from the construction process could help reduce environmental destruction from mining etc., as well as add value to material resource currently defined as waste.[iv]

1.1.3 Many large corporations such as Apple Inc., Caterpillar Inc., Kingfisher plc and others are very concerned about resource security and high levels of taxation associated with corporate responsibility (including dealing with waste/ end of life products)[v]. They are taking issues of re-use and by association principles laid out in 'Cradle to Cradle'[vi] very seriously. The Circular Economy has the potential to galvanise industries that are looking to make money providing services and goods while working in harmony with Planet Earth.

1.1.4 Proving that material currently discarded as waste can make a contemporary public building that performs to very high standards will draw attention to its potential as a valuable resource, potentially reducing the amount of waste created in the future, changing construction techniques to promote low waste alternatives such as off-site fabrication, designing for demolition/ remanufacture, while creating new jobs within this sector.

1.1.5 Learning about designing and constructing buildings is often undertaken in academic and vocational 'silos'. The need to share research data whether academic or 'at the goal face' from a 'live' construction site is particularly important in the UK as many so-called 'low energy' projects do not perform as well as expected when occupied.[vii] The need to understand and then to meet the challenges offered by designing and constructing in an authentic 'circular' or sustainable manner is hugely challenging and currently very difficult to achieve. Getting the whole design team (designers, makers, suppliers and constructors) to work together in a completely inclusive manner in order that they might learn together and from each other, and to document the outcomes from this project is perhaps the main objective of this on-going project.

2. Methodology

2.1 'The House That Kevin Built' 2008

The House That Kevin Built or 'THTKB' was designed utilising two construction systems that promoted the use of timber and plant-based materials. Interestingly both systems were designed by Architects passionate about creating genuinely sustainable developments, with a consideration about the amount of CO_2 emissions and energy consumption associated with the manufacturing process. Both systems specified locally sourced sustainably managed material.

The first system is known as Modcell ®. These are prefabricated panels constructed of highly engineered 400mm deep (front to back) timber box frames in filled with either Limecrete® or straw bales. We used the straw bale system as these heavy weight panels, that exhibit both high levels of insulation and thermal mass, were constructed near to the building site in a barn that Modcell® refer to as a 'flying factory'. Modcell® assemble their engineered frames in the farmers barn and then buy straw from her/him to infill the panels before finishing them off on both sides with lime render. Modcell® can then legitimately claim to be specifying local organic materials. Modcell® panels (approx. 3m wide and 2.7m high) weigh about 1.5 tonnes each, so we used them on the ground floor of THTKB.

We then specified a lightweight ply box construction system using 12mm ply sheet. This system, known as Facit®, was fabricated using a computer controlled CNC Laser cutter. The first floor walls and roof were designed with 3D CAD software. Every Facit® box was individually numbered and cut out with the CNC laser cutter. There was virtually no wastage as the computer ensured that as many panels as possible were cut out of each sheet. The computer ensured an amazing degree of accuracy resulting in no errors on site and therefore no waste material. We used the same CAD system and laser cutter system to create the louvered rain screen cladding to finish off the upper floor external walls. These two systems (Modcell® and Facit®) were assembled on site in less than three days and created the external fabric of the house. The Facit® boxes were filled with cellulose insulation made from waste paper blown into pre-drilled holes in the boxes.

The roof was finished in an array of solar tiles creating electricity and hot water for the under floor heating system. These solar panels were some of the first to be fully integrated into a roof and form the actual waterproof layer.

2.2 THTKB: The re-build.

THTKB took just 6 days to construct. It was filmed and aired each evening on UK Channel 4 TV to over 5 million viewers as ‘Grand Designs Live’. Although a success in as much as this innovative construction project was completed and built on time, the author was frustrated that there was little understanding of why this project was in fact innovative. THTKB was dismantled two days after completion and put into temporary storage.

The author was keen to rebuild THTKB within the grounds of the University of the Brighton where he taught architecture. This would allow the process of re-constructing this unusual to involve architecture, design and construction students, and finally to ensure that this inclusive process became an innovative and effective pedagogic tool.

In 2011 the University of Brighton gifted a piece of land that would locate the project within the campus of the Faculty of Art & Humanities, which crucially was placed in central Brighton. This positioning was crucial to facilitating another ambition for the project, i.e. that of public accessibility. It was envisioned that THTKB would be a community ‘hub’, a place shared by academics and students from the university, as well as local community groups, businesses and schools.

2.3 Developing the design thesis.

In the spring of 2012 the author had a three-month sabbatical from teaching that allowed him to develop the concept of the re-build project. At this time the author met with Diana Lock from Re-Made South East, a government-funded organisation charged with getting larger companies and corporations to reduce the amount of waste their product created in manufacture and crucially in-use. Lock told the author that many large multi-national corporations were very concerned about ‘resource security’ as well as the cost of the ultimate disposal of their products. Companies were looking at ways to avoid relying upon buying large amounts of raw material, as well as avoiding sending their products to landfill or incineration, in order to make or sustain their profit margins, or in some enlightened cases, to reduce their burden upon Planet Earth’s natural resources. The sensible money was investing in the world of the ‘Circular Economy’.

It became apparent that to prove that it was possible to construct a building using waste material it was crucial that this project would not be another temporary shed or bus shelter. We had to create a permanent building, with very high levels of energy efficiency that attained Full Planning and contemporary Building Regulations Approval.

In August 2012 the author called a mini “waste summit” where he met Cat Fletcher who helped form FREEGLE UK “an exchange for unwanted stuff” with over 2.2 million subscribers. The author and Fletcher, together with Dr.Ryan Woodard, a Research Fellow at The University of Brighton who has been working in waste management research for over 15 years, together with Gant and Lock, contrived a plan for redesigning the build so that it was constructed of waste and surplus material from the construction industry. Following Fletcher’s suggestion, they also considered collecting items of waste material currently flooding domestic waste sites; material such as VHS videotapes and CD’s. The idea developed from that of focusing only on waste from the construction industry, to a project that would raise awareness of how wasteful we all are going about our everyday domestic lives. This would open up the project to a bigger audience as well as change it

from an exemplar construction project that could directly inform the construction of many other buildings, to a project more akin to a polemic, a thought provoker, or as RIBA Awards Judges noted: “*The Brighton Waste House has sufficient scientific integrity to be taken seriously by the construction industry and just enough political clout to influence recycling policy. It is clear this interesting project will continue to question important issues of recycling that affect everyone*”.
Source: RIBA Jury citation ‘The Stephen Lawrence Prize 2015’

2.4 Developing the detail design.

It was agreed that this building, which is actually university teaching accommodation, not a house at all, should be designed to be as energy efficient as possible. Due to the unusual constraint of being built with waste the design team didn’t try and deliver a design that met Code for Sustainable Homes or BREEAM requirements. Instead environmental engineers ran an IES (Integrated Environmental Solutions) digital model to set energy efficient ‘benchmarks’ relating to the site, the programme, the form & orientation, levels of ‘U’ Values required through the external fabric, as well as ideas for the cost effective primary energy source (conventional and renewable). It was decided that the building would be all-electric as far as heat and power were concerned due to services constraints on site. The mechanical, electrical and power installations would be designed to be as efficient as possible: the building would not show an array of ‘green technologies’ as many ‘demonstration eco houses’ do as these buildings are often over complicated and too expensive. We wanted to prove that this low energy building made of waste would be cost effective, fuel efficient, and that it could be built on time and on budget.

The first challenge was to decide on the design of the load-bearing walls or frame for the building. The team had previously been successful at sourcing second-hand timber from skips and ply sheeting from large top tier construction contractors for temporary pavilions exhibiting student architects work. So it was decided to take advantage of this by designing a timber and ply frame comprising 400x400mm section beams and 400x400mm section columns at approximately 2.5m centres. In between the columns we designed 400mm deep, 900mm wide and 2400mm high ply boxes (like cupboards). We called these boxes ‘cassettes’, which would later prove a bit confusing. However, it was these cassettes that provided the opportunity for collecting and in effect storing waste material from sources other than the construction industry.

A 4kW array of photovoltaic solar panels sits on the largest South-facing facet of the roof. It provides approximately 25% more electricity than the building requires over a year.

Current Building Regulations ‘U’ Value levels for the roof, external walls and ground floor were achieved by applying ‘returned’ and/ or damaged polyurethane insulation (normally used in the construction of buildings) secured to the outer face of the 400x400mm timber box frame and ‘cassettes’. This 400mm external ‘wall zone’ was used for ‘storing’ waste material, either heavyweight material providing internal air temperature stabilising ‘thermal mass’ or lightweight material providing, to various degrees of success, additional insulation. All walls were to be monitored for condensation, temperature and off gassing.

External windows and doors were supplied as new high performance units. Second-hand units are not easy to source and their thermal effectiveness could not to be relied upon.

The design of the foundations and ‘over-site’ was agreed as low carbon concrete, i.e. concrete with a 40% reduced cement content (replace with pulverized fuel ash) plus aggregates from demolished concrete buildings. It should be noted that the Local Authority Building Control was hugely supportive of this project allowing us to develop the rest of the design during the construction of the building. The Building Control Officer even attended design development meetings on site.

2.5 The Construction Team.

The Mears Group, a national contractor charged with servicing and maintaining a large percentage of UK's social housing stock, contacted the author in early 2011 stating that they were keen to help build the project as they had a healthy apprenticeship scheme in Brighton and wanted their apprentices to work on the project. In the spring of 2011 the Mears Team stabilised the ground on site, constructed the foundations, installed the drainage and cast the ground floor slab for the Waste House. Whilst completing these works their apprentices help architecture students on an adjacent site on the same campus build the first temporary pavilion to show final year projects in the graduation show. This process was such a success that Mears decided to help build the rest of the Waste House. Mears also agreed to provide an experienced site agent to run the construction site, together with their apprentices. We planned to start works on site in the autumn of 2012.

It was during this period that the author had a fortuitous meeting. He went to meet tutors delivering construction courses at City College Brighton and Hove, as he wanted to see if they could construct a glue-laminated timber beam for the roof of the building. City College couldn't make a glue-lam beam, but they wanted to build the Waste House as every year they build the equivalent of a new in their three story workshops. In addition to this the team employed Cat Fletcher of FREEGLE UK to source waste material for the project. We had our team.

3. Results

3.1 The construction & learning process.

Mears took control of the construction site and were responsible for security, coordination and all aspects of health and safety. In addition Mears supplied up to four apprentices every day. However they were on standby to do 'normal' Mears work on nearby housing estates, so they would often have to leave site. Mears were our 'Main Contractors'. In addition to this we had City College student carpenters, electricians, plumbers, bricklayers, decorators etc. supervised by their qualified tutors. They were our 'Sub-contractors'. City College students would be on site two or three times a week, although the site agent wouldn't know if he had two students to work with or thirty. Managing a construction site with an unknown number of relatively untrained sub-contractors was one of the biggest challenges for this project. Despite this the building frame was constructed within 3 months by students in City College workshops and then assembled and completed by 360 students, apprentices and volunteers on site in only 12 months. In addition we had specialist suppliers who would often install their products or systems in partnership with our young constructors and their tutors.

During the on-site construction period there was a Volunteer Summer School Camp that ran from June 2013 until September 2013. Over 50 students completed the most challenging part of the construction process during this period, i.e. the vaulted roof structure. 25 of the volunteers were City College students, and another 25 were architecture students, with many of those from the Interior Architecture School. This was perhaps the most profitable time as far a skills and learning exchange amongst students, apprentices and the one or two professional trades people we had on site. It was the one period of time where design students could spend three, four, maybe six weeks in a row working on site. Some of these committed design students became so adept at their new trade that they ran small teams of volunteer carpenters on site; teams that included City College carpentry students. It was during this time that Mears promoted five City College students to Apprentices because of their work on our project. A number of our students received Achievement Awards from Mears.

We also welcomed over 750 pupils from local primary and secondary schools, as well as other technical colleges from around the South East. This unusual learning environment was completely facilitated by our immensely patient site agent David Pendegrass who had to do a Health & Safety Induction for every person who arrived on site, whether they wanted to work or simply visit, and remember he also had to get the Waste Hose built on budget and on time. This he did.

3.2 Locating appropriate waste material.

The author would meet the construction team on site every week to check progress and identify materials and products that needed to be sourced. Often the conversation would involve the site agent and Cat Fletcher. There were basically two strategies put into place to find material. The first strategy was the conventional one. Mears, BBM and City College Brighton & Hove employed their contacts and networks within the construction industry to source second-hand, surplus and waste construction material. The second strategy was less conventional. Cat Fletcher used her FREEGLE UK social media networks (FREEGLE UK has over 2.2 million subscribers with 18,000 in Brighton & hove) to locate waste material. Individuals, local authorities, building contractors & suppliers, schools and businesses from all over UK supplied the project with materials such as 25,000 toothbrushes from Gatwick Airport, 2 tonnes of waste denim, 4,000 VHS video cassettes, 4,000 DVD's.

In addition the author sourced waste material from demolition sites his practice BBM were working on. UK VAT rules dictate that retrofit and extension works to residential properties attract VAT at 20%. However new-build residential projects are 'zero rated' and attract no VAT. BBM were working on a project where the VAT was in excess of £360,000. The client instructed that his home be completely demolished for less than £10,000 to avoid this VAT. BBM collected timber from the demolition and re-used it to form the vaulted roof structure of the Waste House.

3.3 Utilising waste from the Waste House.

It is estimated that over 40 tonnes of waste was diverted from landfill or incineration by constructing the Waste House. However the process of constructing the Waste House created waste material. Whenever possible we set up projects using this material. Architecture students created designs and built them after locating and using waste from the Waste House. In addition a local 'zero waste' restaurant called 'Silo' constructed tables and shelving from surplus material from the Waste House. A local community group used waste material to create chairs, and an allotment shed in Hollingdean used surplus carpet tiles, vinyl banners and timber from the Waste House.

3.4 Specifying new material and products.

There are a number of products and systems that contemporary buildings require where it is not possible to install as second-hand. Electrical circuits comprising wire stripped out of buildings will require too many joints or junction boxes to be reliable. Second-hand above and belowground drainage and waste pipes are technically a health hazard and not appropriate to re-install without a professional cleaning operation. We sourced second-hand light fittings: five of them from a scrapped 60 years old container ship. However light bulbs have to be new. In short it is difficult to install what the construction industry calls 'first fix' services: piping work and wiring. However the 'fittings' such as sinks, wc pans, IT equipment, Mechanical Ventilation and Heat Recovery system, and even flat screens for presentations were second-hand and straight forward to sourced.

3.5 Achieving Building Regulations Approval.

As mentioned earlier, Brighton & Hove City Building Control were very supportive and an integral part of the design team, attending design and progress meetings. Installing dvd's, videos, and denim into external wall cavities does not test Building Regulations as they are separated from the internal environment by the internal wall linings. The Waste House is constructed primarily of timber and ply sheets with various second-hand plastics acting to a greater or lesser extent as low-grade insulation. Most homes built in the UK in 21st Century are timber framed with plastic insulation infilling wall cavities and plastic vapour control membranes sitting behind internal plaster or timber wall linings: pretty similar to the Waste House in fact.

The most challenging aspects for the Building Control Officer were proving the fire and flame resistance of the 2,000 second-hand carpet tiles used for external wall cladding, and the ply wall linings used in the main first floor studio. To satisfy these queries we set up a test rig of 15 carpet tiles fixed on a brick wall, as they would be installed on the Waste House. In the presence of the Building Control Officer our site agent directed a hand-held blowtorch onto the tiles for 5 seconds and then for 10 seconds. On both occasions the tiles started to smoke quite heavily. However as soon as the blowtorch was taken away the tiles immediately extinguished.

The first floor wall linings were more straightforward. They were constructed of third-hand ply sheet that had previously been used by the team to created a 9m high 'waste totem' at EcoBuild 2013. Material for the totem had to be flame proofed before it was decorated with second-hand paint and installed in the exhibition hall. This flame retardant ensured that we could re-use this material as the internal wall finish of the first floor studio space without any fear of Building Control not approving it fit for purpose.

3.6 The academic legacy.

Since the spring of 2011 the themes and challenges embraced by the Waste House have been influencing the core delivered curriculum of the undergraduate architecture and interior architecture courses at the University, as well as at in partner institution City College Brighton and Hove. Baker-Brown coordinates architecture 'technology' and 'practices'. Both modules used the process of designing and then constructing the Waste House as an inspiration, awareness raiser, and vehicle to deliver RIBA approved learning outcomes.

Architecture students considered design projects tackling issues associated with valuing waste as a resource, as well as broader issues relating to the Circular Economy. One undergraduate architecture student designed a timber construction system that inspired the 'cassettes' used in the Waste House. Construction students from City College completed learning modules of their carpentry, electrics, plumbing, brick laying, plastering, decorating and maintenance by working initially in the workshop, but then crucially on the 'live' construction site. Both the author and Fletcher delivered lectures to both City College construction students as well as architecture students as part of their core curriculum. They also gave presentations about waste and designing for a circular economy aimed specifically at children and young learners as young as 6 years old. As part of the university's on-going Widening Participation Programme over 750 young people were shown around the construction site during the construction period they presented to.

Students from regional tertiary colleges visited the site, as well as other students from the School of Science and Engineering. Since its completion the Waste house host's regular school visits on Wednesdays where open design workshops are held.

While on site a Jordanian PhD student approached the University asking if he could be involved in the digital monitoring of the external wall fabric. He moved to UK to do just this.

Since the inception of the project in 2010 the University of Brighton has hosted a website focusing on the development of the Waste House as an idea through to completion. It is regularly updated and serves as an archive and learning resource.

In March 2013 the author and Gant curated a 3-day seminar entitled ‘The WasteZone’[viii] where 12 guest speakers discussed the idea of waste as a valuable resource from many different perspectives. The Waste House team also designed and erected the 9m tall ‘Waste Totem’ drawing the attention of the 65,000 visitors towards issues of Re-Use. Since this event UBM who own ‘EcoBuild’ have started up a new re-use themed ‘zone’ of their own called ‘Resource’ situated within the larger exhibition. We feel that we may have had a small role in enabling that to happen.

The Waste House also hosts the University of Brighton’s Sustainable Design MA with students working in the first floor studio 2 days a week. Prof. Jonathan Chapman and Nick Gant have their office on the ground floor. Community groups, local schools & other educational establishments, as well as local and international businesses, and local authority groups use the Waste House. The building hosts meetings, lectures and symposia with large construction contractors as well as commercial enterprises such as Body Shop and Marks & Spencer’s.

This is an on-going research project, involving new generations of students being set projects testing, improving and updating the Waste House whose performance is being constantly monitored by the School of Science and Engineering.

However perhaps the biggest legacy the Waste House project leaves is that of raising awareness of the negative issues associated with society’s linear, throwaway, consumer-led lifestyle. The building has many stories associated with the materials collected and residing within it. For example an airline cabin service company at Gatwick Airport collected 25,000 plastic toothbrushes for the project in only 4 days. These statistics stop you in your tracks are it were, and we believe get you thinking about where stuff comes from and where it currently ends up. Perhaps it will also get more people realising the potentials for re-use and more particularly the potential for designers to play a huge part in our future Circular Economy, and of course to understand “that there is no such thing as waste, just stuff in the wrong place”. Source: treehugger.com 2011

Since it opened in June 2014 over 400 articles have been published around the world, in newspapers, on tv & radio as well as on many websites. The project has attracted an enormous amount of interest.

3.7 Capturing the design and construction process.

We commissioned a graduate from City College Brighton & Hove’s film school to record the whole process and edit approximately 25 short films. An additional 20 short films were shot of the completed building explaining the reasoning behind the design decisions as well as the many stories behind the sources of the materials used. All films were put on line on the Waste House website which went live at the beginning of the build and is still ‘live’ and updated.

4.0 Lessons learnt.

4.1 That designing structural beams and columns using second-hand, waste and surplus material raises unusual challenges for a structural engineer. If you don't know where the timber materials originate from you won't know the stress grade and therefore the actual strength of the product. Our structural engineer therefore had to assume it was the weakest material on the market. This initially manifested itself in a draft design from the engineer that suggested larger structural beams and columns than normal. This design proposed using far more material than would be normal. It was only when the design was refined over a number of weeks, so that it became more specific to the actual loads on each structural member, that if became more material efficient.

4.2 In addition, during the manufacture of these elements the structural engineer had to oversee and approve every structural element in the workshop: they were constructed by young people with as little as two months time spent on a carpentry course.

4.3 The team designed a timber-framed building assuming we could source over 400 sheets of waste ply and approximately 2km of timber studwork: we had after all done this before when constructing temporary graduation pavilions. However in 2012 we were not able to do this as it rained during every month. Initially we were receiving water saturated and delaminated ply that was not appropriate to use. It took the team two months to find damaged ply suitable to use and delayed the project. We learned to find material first and then think about how it might be useful or not, instead of designing while assuming materials would be available: a completely different process to normal.

4.4 Materials would often be offered weeks or even months before they were needed. It was crucial to the success of this project that we could store material keeping in safe and dry. Brighton & Hove City Council let us borrow a building nearby to use as a temporary resource store.

4.5 If properly briefed and supported, young people with limited skills and experience within the construction industry, can construct a building using unusual materials that performs at very high levels of energy efficiency.

5. Conclusion

The Brighton Waste House started out as a design & build project, as well as an inclusive learning process to prove that construction waste and surplus material was worth salvaging and not throwing away. Via further research and a policy of inclusive design the project evolved into more of a polemic rather than an exemplar for the UK housing industry to copy. The Waste House is a vessel containing hundreds of stories associated with the salvaged materials it contains. These stories and narratives that run through the project resonate through the building and ensure that students, consultants, academics, and whoever asks questions when they use the building, will know more about where stuff comes from and where it normally ends up, and then perhaps they might ponder upon how things might be done differently: how our unintelligent 'linear economy' that finds materials, processes it into things that we then throw away, could be changed into a 'circular economy' where materials and goods are in a state of perpetual re-use.

The Waste House acquired over 40 partners during its development. Many of these partners are able to use the building. Schools visit the Waste House and take part in sustainable design workshops with designers, poets, writers, artists and constructors. The University of Brighton's MA in Sustainable Design is based in the building, and many community groups use it as well.

The unusual external fabric of the building is being monitored to see how it performs compared with more straightforward materials. This information will be published in due course.

Over 450 articles have been published around the world via newspapers, web-based magazines, tv and radio. This project has got people speaking about waste as a valuable resource. To date it had won 10 awards and is currently nominated for 5 more. It appears to have struck chord.

The author is currently writing a book entitled 'The Re-Use Atlas: a designers guide towards a circular economy'. This book has been inspired in part by the research undertaken by the author as his colleagues, as well as future initiatives such as 'Resource Mapping' or 'Harvest mapping' where architects redefine what is meant by 'locally-sourced' materials by including existing waste, overlooking, surplus material and resources literally lying around near to or on the development site (including valuing the existing buildings themselves).

The Waste house still inspires student on campus as new generations are encouraged to add their design ideas to the building. It is an on-going 'live' research project. It has also ensured that the team comprising different academic and vocational establishments, the local authority and local contractors are currently bidding for European grants for future collaborative innovative construction projects, and the idea of a 'Live Projects Office' is a reality for the Faculty of Arts and Humanities.

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Development of a cost-effective sustainability assessment method for small residential buildings in Germany: Results of pilot case studies

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Summary

Available systems to assess the sustainability performance of small residential buildings in Germany have so far not achieved widespread application due to a complex list of criteria and the costly implementation. Therefore, a new methodology apapted to the needs of detached and semi-detached houses was developed in the context of a research project. To ensure the suitability, the assessment system was tested in a pilot phase involving 18 real case buildings. From November 2015 on the new system will be available for general use.

Keywords: sustainability assessment methodology, sustainable certification, small residential buildings, pilot case study, Germany

1. Introduction

In the past few years a promising approach to support sustainability in the building industry was created with the development of different methods to assess and certify the sustainability of various building types. Today numerous assessment methods are available on the national as well as on the international level. Back in the 1990s, first sustainability tools such as the British system BREEAM and the American label LEED were developed and introduced on the market. In 2009 the DGNB certificate of the German Sustainable Building Council (DGNB) and the Sustainable Construction Evaluation System (BNB) of the Federal Ministry of the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) were established on the German market. In contrast to traditional assessment methods, they pursue a holistic approach throughout the whole life cycle of a building instead of focusing primarily on ecology and energy efficiency.

However, in Germany the focus was so far set on building types such as office buildings, schools, industrial buildings or large residential buildings. Small residential buildings in contrast have not obtained enough attention to date, although detached and semi-detached houses make up a considerable part of 45 percent of new construction projects within the housing sector [1]. In 2012 the Sustainable Construction Quality Label (NaWoh) was developed with support of the Ministry for Transport, Building and Urban Development (BMVBS). 12 projects have been assessed so far, but the system is only applicable to residential buildings with more than five dwelling units. Furthermore the German Association for Sustainable Building (DGNB) established the system variant “Small Residential Buildings” for houses with less than six dwellings, but only four certifications have been carried out to date. Due to a complex list of criteria and the costly implementation the assessment system has not achieved widespread application so far.

Abroad residential buildings have been assessed against sustainability criteria for many years. 462.500 dwellings have been certified under the BREEAM “Code for Sustainable Homes” system. The high number can be explained by the UK government’s decision in 2008 to enshrine in law the sustainability assessment of buildings [2]. The numbers of certifications under the American LEED system or the Swiss Label Minergie in the housing sector are also increasing constantly [3] [4].

With an average of 110.000 new detached and semi-detached houses being built each year in Germany, a cost-effective, simple assessment method for small residential buildings that all clients can apply, and that is designed to encourage sustainability in small residential buildings, is needed. An enquiry conducted in 2014 on the topic of “Clients and Sustainability” showed that 73% of the clients are interested in owning a sustainable building, and that they would appreciate a certificate that confirms that the house is built in in a sustainable, environmentally-friendly, energy-efficient manner [5].

For this reason, a new assessment method designed to the needs of detached and semi-detached houses was developed in the context of a research project on behalf of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). In a second step the assessment system was tested and adapted in a pilot phase study involving 18 real buildings. The objective of the paper is to give an insight into the assessment method and point out the suitability for small residential buildings.

2. Methodology

2.1 Phase I: Analysis of existing assessment methods for residential buildings

2.1.1 Criteria and indicators

At the beginning of the study existing assessment methods for residential buildings as well as current research projects and standards concerning the field of sustainable building were analysed. Criteria and indicators were reviewed in a two-step procedure. In a first step the research team examined whether existing criteria and indicators would work for detached and semi-detached homes. In a second step the technical and economical practicability and the time required for assessing the criteria and indicators was determined and compared to the results of step one. Based on the outcome of the analysis, the existing indicators were adopted unchanged, adopted with modifications or not adopted. The result was a catalogue consisting of 18 criteria and 29 indicators in the categories of sociocultural and functional quality, environmental quality, economic quality and process quality based on the methodology of the Sustainable Construction Evaluation System (BNB). The categories technical characteristics and site are not rated which contributes to the simplification of the assessment system for detached and semi-detached homes.

Fig. 1 Sustainability qualities

2.1.2 System Boundary

The evaluation of existing assessment methods showed that the term “small residential building” is not clearly defined in the field of sustainability. In order to adapt the newly developed system for detached and semi-detached houses, the system boundary was defined according to the Model Building Regulation (MBO). This includes buildings with a height of maximum seven metres and not more than two units. The gross floor area of the whole building may not exceed 400 square metres [6]. To ensure comparability between the different projects, gardens, terraces, garages etc. are not considered in the evaluation.

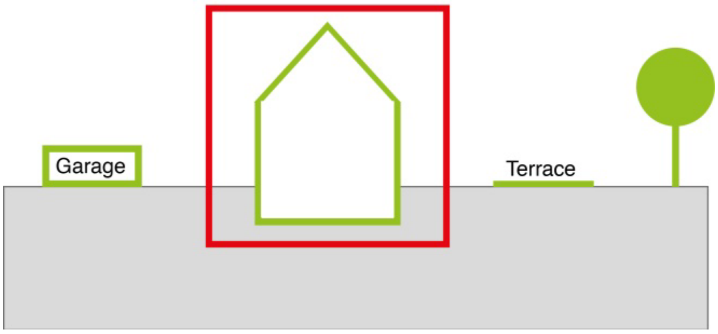

Fig. 2 System boundary

2.2 Phase II: Evaluation of the developed assessment method for small residential buildings

2.2.1 Adaption of criteria and indicators

In order to check the assessment method’s suitability, a pilot case study involving building-owners, developers, architects and engineers was carried out. The different stakeholders were asked to apply the newly developed assessment method to real existing buildings. Overall 24 projects were accepted for the pilot case studies including

- 16 detached houses,
- one detached house with a secondary suite,
- one semi-detached house,
- four terraced houses,
- one building consisting of two flats above a shop unit and
- one conversion of a barn to a residential building.

During the pilot phase three workshops were held to train the participants in the content of the assessment system. At the same time the participants assessed their pilot projects applying the list of criteria. Criticism and suggestions during the workshops were taken into consideration for the further development of the assessment system. After each workshop the list of criteria and indicators was adapted to the outcomes. This lead to different versions (V0.2, V0.3, V0.4, V0.5) during the workshop phase. After their completion the submitted pilot projects were checked for correctness by the research team. In addition, the participants of the workshops were asked to fill in a form for every indicator questioning time and costs required for assessment and availability of required documents. Finally, the results of the pilot case studies as well as the questionnaires were analysed to adapt the assessment method. The outcomes are reflected in version V1.0 – the current version for the market introduction.

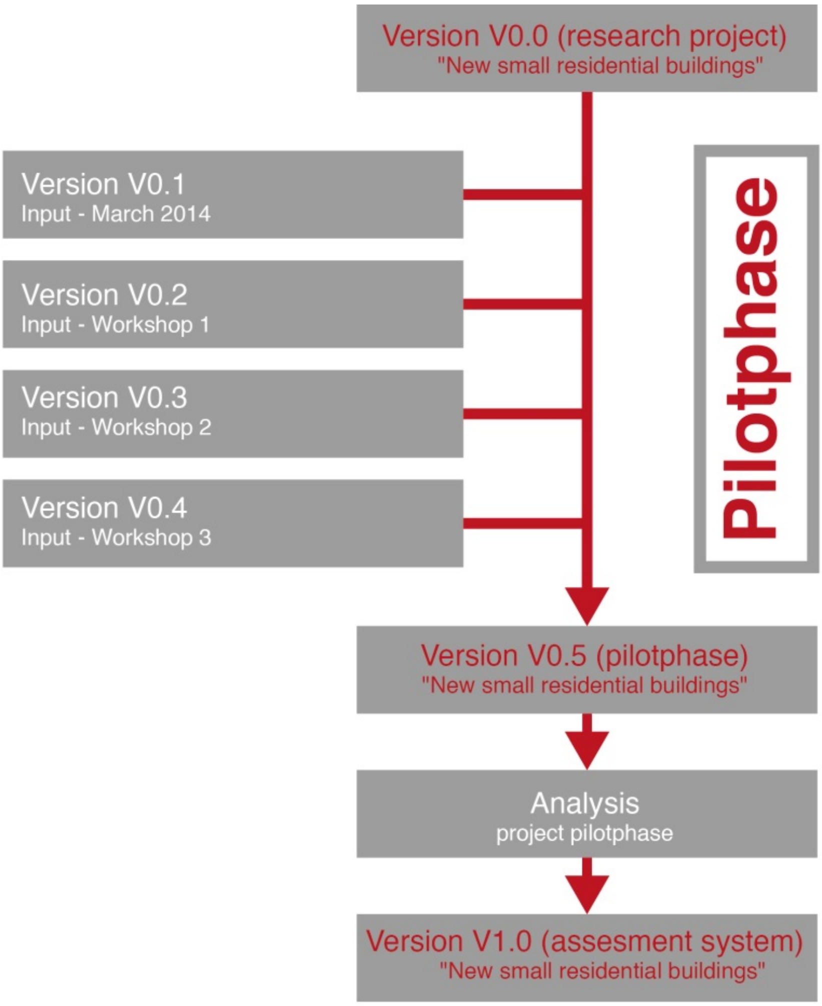

Fig. 3 Different versions of the assessment system

3. Results

3.1 Phase I: Development of a sustainability assessment method for small residential buildings

In summary the research project's result of phase I was a set of 18 criteria and 29 indicators (version V0.0) shown in table 1. The criteria and indicators are divided up into four categories. In contrast to existing assessment methods, the sociocultural and functional quality comes first in the list of criteria instead of the environmental quality as social factors play an important role within the field of housing. The categories technical characteristics and site are not rated [7].

3.1.1 Sociocultural and functional quality

The quality of life, comfort, safety, security and adaptability offered by the building are all assessed. The level of comfort is determined by measuring the building physics characteristics, making calculations regarding thermal, acoustic and visual comfort, and by assessing the inherent level of hygiene inside the building. The system helps to enhance the residents' quality of life as the aspects of safety and security, accessibility and the user-friendliness of the building services are also considered [8].

3.1.2 Economic quality

The category "economic quality" aims to determine selected costs occuring during the building's life cycle, and to assess its long-term viability. The calculation of life cycle costs is based on the standard DIN 276 (Building costs – Building construction). Long-term viability is determined by the assessment results for the indicators accessibility and thermal insulation in summer, as well as the extent to which energy efficiency figures exceed those demanded by the German Energy Saving Regulation, the extent to which the client has been briefed to enable them to maintain the building's value over time and the extent to which the rooms are designed in a neutral way to allow for alternative uses [8].

3.1.3 Environmental quality

The environmental quality of small residential buildings is determined by carrying out a life cycle assessment (LCA). The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and the German Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) provide the online tool "eLCA" for this purpose. The LCA depicts the building's entire life cycle, now including not just the building fabric itself, but also the building services. Primary Energy Consumption and Global Warming Potential are the most important indicators, but other aspects such as decentralised energy generation, recyclability, use of local or certified wood, and efficient use of space in order to minimise soil sealing, are also considered [8].

3.1.4 Process quality

The main goal of the category "process quality" is to assure the quality of planning, construction and documentation, and to provide a building dossier including a user manual. The building dossier contains the latest plans, energy performance certificates, measurement records, safety certificates, data sheets, care instructions, and all documents relevant to the operation and maintenance of the building. Process quality also means quality insurance assessed by measurements and verification of construction quality by an external assessor [8].

Table 1 List of criteria and indicators (version V0.0)

Category	Criterion	No.	Indicator
1. Sociocultural and functional Quality	**1.1 Healthy housing**		
		1.1.1	Interior hygiene
		1.1.2	Healthy drinking water
	1.2 Thermal comfort		
		1.2.1	Thermal insulation in summer
	1.3 Visual comfort		
		1.3.1	Available daylight
	1.4 Sound insulation		
		1.4.1	Airborne sound insulation against noise from outside
		1.4.2	Airborne sound and subsonic noise insulation inside the building
		1.4.3	Structure-borne sound insulation
	1.5 Ease of controlling building services		
		1.5.1	User-friendliness and informativeness of controls
	1.6 Safety & security		
		1.6.1	Anti-intruder measures
		1.6.2	Fire alarms and firefighting
	1.7 Accessibility		
		1.7.1	Accessibility
2. Economic Quality	**2.1 Life cycle costs**		
		2.1.1	Selected life cycle costs
	2.2 Stability of value		
		2.2.1	Long-term viability of building
3. Environmental Quality	**3.1 Enviromental impacts**		
		3.1.1	Life cycle assessment - global warming potential / carbon footprint
		3.1.2	Life cycle assesssment - ozone depletion potential / ozone hole
		3.1.3	Life cycle assesssment - photochemical ozone creation potential / summer smog
		3.1.4	Life cycle assesssment - acidification potential / acird rain
		3.1.5	Life cycle assesssment - eutrophication potential / overfertilisation
		3.1.6	Prevention of harmful emissions into the environment
	3.2 Energy		
		3.2.1	Life cycle assessment - primary energy demand non-renewable
		3.2.2	Life cycle assessment - total primary energy demand and share of renewable energy
		3.2.3	Decentralised energy generation
	3.3 Raw material consumption and waste generated		
		3.3.1	Ease of deconstructing
	3.4 Biodiversity		
		3.4.1	Use of local / certified wood
	3.5 Drinking water consumption		
		3.5.1	Use of water-saving taps and mixers
	3.6 Land use		
		3.6.1	Efficient use of available space
4. Process Quality	**4.1 Project preparation**		
		4.1.1	Consultation and agreeing objectives
	4.2 Property documentation		
		4.2.1	Building dossier including user manual
	4.3 Quality of construction work		
		4.3.1	Quality assurance

4.1 Phase II – Adaption of the sustainability assessment method as result of the pilot case studies

4.1.1 Criteria and Indicators

The set of criteria and indicators (version V0.0) was revised according to the outcomes of the pilot phase. An analysis showed that the original assessment method was widely applicable for the most part. The biggest differences between research and practice emerged among the legal requirements for safety and security (indicator 1.6.1), accessibility (indicator 1.7.1) and harmful emissions into the environment (indicator 3.1.6). It was obvious that the required standards do not always comply with the building practice. Due to unavailability of certain construction products, certificates and costly implementation those criteria were modified. The indicator “Prevention of harmful emissions into the environment” was postponed in the context of the pilot case study, but should be readopted after further research. In the field of Life Cycle Assessment (indicators 3.1.1 - 3.1.5 and 3.2.1 - 3.2.2) the method was limited to the parts Global Warming Potential and Primary Energy Demand. The values for Ozone Depleting Potential, Photochemical Ozone Creation Potential, Acidaon Potential and Eutrophication Potential still have to be shown, but will not be included in the result. The indicator “Long-term viability of building” was deleted as it double assesses other indicators. Furthermore, the benchmarks of other indicators were adapted slightly. After this modification the assessment system now consists of 19 indicators and represents version V1.0 - the version for market introduction. To arrange the list of indicators more clearly, the categorie „indicator” was deleted. Thus the former indicators became criteria [9].

Table 2 List of criteria and indicators (version V1.0)

Category	No.	Criterion
1. Sociocultural and functional quality	1.1.1	Healthy housing: Interior hygiene
	1.1.2	Healthy housing: Healthy drinking water
	1.2.1	Thermal insulation in summer
	1.3.1	Available daylight
	1.4.1	Sound insulation
	1.5.1	Controlling building services: User-friendliness and informativeness of controls
	1.6.1	Safety and security: Anti-intruder measures
	1.6.2	Safety and security: Fire alarms and firefighting
	1.7.1	Accessibility
2. Economic quality	2.1.1	Selected life cycle costs
3. Environmental quality	3.1.1	Life cycle assessment - Global Warming Potential and other environmental impacts
	3.1.2	Life cycle assessment - primary energy demand
	3.2.1	Decentralised enegry generation
	3.3.1	Use of local / certified wood
	3.4.1	Use of water-saving taps and mixers
	3.5.1	Efficient use of available space
4. Process quality	4.1.1	Consultation and agreeing objectives
	4.2.1	Building dossier including user manual
	4.3.1	Quality assurance

4.1.2 Structure and methodology

Furthermore, the structure and the methodology of the assessment system for small residential buildings were discussed in the context of the pilot phase. It was specified that the four categories (sociocultural and functional quality, economic quality, environmental quality and process quality) should count the same in terms of sustainability. Thus each of the four categories accounts for 25% of the overall result.

For each indicator there is a description of the assessment method, general information, an assessment scale, and the documents required as evidence of adherence. The result of the assessment is represented by a score between 1 to 5, and a percentage:

- 80% or more: excellent (score of 1,5 or better)
- 65% or more: very good (score of 2,0 or better)
- 50% or more: good (score of 3,0 or better)

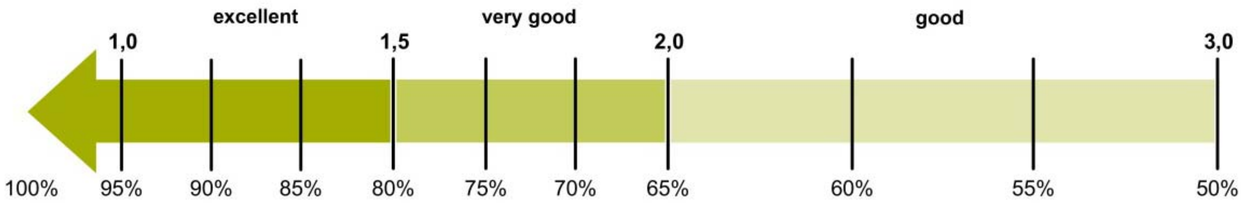

Fig. 4 Assessment levels

Based on this system the pilot projects were assessed. Finally 18 projects out of 24 handed in their documentation for conformity check. The results of the certification process ranged from 50.98 % (score: 2.9) to 85.1 % (score: 1.3).

5. Conclusion

Based on the analysis of the pilot case studies a simple, cost effective and marketable assessment system for small residential buildings was developed. From November on, the system will be available for general use and will be extended to cover residential buildings with up to five units. In order to make the necessary building documentation easier, an online platform will be developed. Assessment will in the future be carried out by “Sustainability Coordinators” who are specially trained in sustainable building and monitor the project during construction phase. To ensure the quality of the certification process, assessments will be checked by an independent institution. From 2016 on, the KfW Banking Group could possibly provide financial support, similar to the support for the Efficiency House standard, for building-owners seeking to achieve a sustainability certificate for a small residential building. Furthermore it is conceivable that there will be a variant of the assessment system for refurbishment work on existing residential buildings [8].

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Development of a Raw Material Model for Urban Systems – A Contribution to Support Material Flow Analysis and Resource Management

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Summary

The major aim of this project is to analyse the raw material flows over the whole life cycle of urban areas. The basis for this inventory sets the identification of what types of materials and how much are contained in different building types and selected infrastructure of the German building stock. Furthermore a developed life cycle model can give an indication at what times raw materials are required (e.g. insulation for retrofit measures), and when raw materials become available again, for recycling or disposal, after the end of life of individual components of the analysed area.

Keywords: Resource efficiency, material flow analysis, urban mining, raw material use, construction materials

1. Introduction

According to estimates of the German Federal Ministry for the Environment, the German building stock contains around 10.5 billion tonnes of mineral building materials, around 220 million tonnes of timber products and around 100 million tonnes of metals. Due to continuous building activities, especially renovation and retrofit measures, it is estimated that this raw material stock will grow by a further 20% until 2050 [1]. The building sector is one of the most resource intensive economic sectors in Germany. The German National Strategy for Sustainable Development sets targets of doubling the raw material productivity until 2020 based on 1994 levels [2]. The developed raw material flow model for the building industry that is described within this paper can aid in reaching these proposed targets.

2. Model Development

The major aim of this project is to analyse the construction related material flows over the whole life cycle of urban areas. The basis for this inventory sets the identification of what types of materials and how much are contained in different building types of the German building stock and selected infrastructure such as roads. Furthermore a developed life cycle model can give an indication at what times raw materials are required (e.g. insulation for retrofit, or new construction), and when raw materials and potential pollutants become available again, for recycling or disposal, after the end of life of individual components of the analysed area.

The developed raw material cadastre can then be integrated into geographic information systems (GIS), such as the CityGML standard as an additional layer and be linked to energy information for example (e.g. heating demand), to analyse the influence of raw material flows on the energy consumption of individual buildings and the analysed area as a whole. As the individual material flows (life cycle inventory) will be identified, it will also be possible to link this information to life cycle assessment (LCA) data to identify the environmental impacts (e.g. CO2 emissions) the continuous changes of urban systems and the anthropogenic stock may have.

This integrated approach is not only examining the life cycle of material flows of urban systems over time, but it also tries to link and provide an interface to existing systems and calculation methods, to move towards rating the overall resource efficiency over time. As stated in VDI 4800, a conclusive rating of the overall resource efficiency of systems can only be achieved if the use of all natural resources is being quantified and then placed into relation with each other [3].

The continuous spatial-temporal model will be able to capture how urban spaces change over time, from a raw material perspective. The 3D/4D model will be feed with actual data, where 3D indicates the spatial dimension, such as building geometries obtained from 3D city models (e.g. CityGML standard) and the fourth dimension (4D) represents the temporal dimension.

The object orientated modelling language, Universal Modelling Language (UML) was chosen to link the relevant attributes and influence factors which represent the complex structure of urban systems. This object orientated approach is a transdisciplinary approach and allows room for future expansion to provide a link to other models, beyond the system boundaries of this project. These links are very important as many different factors from different disciplines need to be considered to accurately model the dynamics of changing complex systems, in this case urban spaces.

3. Methodology

A combination of bottom-up- and top-down-assessment is used to identify the material flows.
The bottom-up-method aggregates the composition of individual buildings and infrastructure, such as roads. Existing information on the material composition of building categories (typologies), grouped by building age and type will be used to feed the model. This includes existing datasets, such as the catalogue of the “Institut für Ökologische Raumentwicklung (IÖR)” or “Institut für Wohnen und Umwelt (IWU)” typologies. Data for the primary energy consumption of different building types and standard building components for example can also be abstracted from these sources. Historical data, life-cycle-assessment data of individual buildings, demolition data and case studies will also be used.

The top-down-method will make use of national statistics, such as production figures for the selected raw materials.

3.1 Bottom Up Approach

For the bottom-up approach GIS has shown to be an ideal tool, as unlimited building information, not only on material consumption can be added to 3D city models. Building geometry and the geometry of individual components (e.g. wall areas, window area, roof area and type and other information) will be taken from existing 3D/4D city models, depending on the available level of detail (LOD). For many parts of Germany a comprehensive LOD 2 model is available, which has an accuracy of about 1 meter and shows a buildings individual roof type. LOD 3 models have a higher accuracy, and can show individual openings of facades (e.g. windows and doors). LOD 4, also referred to as walkable architectural models can provide information such as a building's interior.

Developments in GIS and Building Information Modelling (BIM) methods have made it possible to construct higher level of detail (LOD) models, such as full architectural models. With the aid of 3D surveying techniques, which create so called point-clouds, these higher level of detail models can be constructed. This process is however very time consuming and expensive, especially when looking at the scale of a city or cluster. For these reasons LOD 2 models will be used as input data for the model.

Together with the building age and type, combined with material composition data extrapolations on the construction stock can be made. An example of the results of one case study is shown in Table 1, where detailed information on materials in a multi-family building in Munich constructed in 1962 has been collected.

Table 1: Material consumption of a multi-family dwelling constructed in 1962

			Material Intensity	
Material	Total Weight (t)	Total Weight (%)	(t/m^2 BGF)	(t/m^3 BRI)
Bitumen	4,3	0,07	0,0008	0,0003
Insulation	22,0	0,34	0,0039	0,0015
Ferrous metals	148,6	2,32	0,0266	0,0101
Glass	5,6	0,09	0,0010	0,0004
Timber	54,6	0,85	0,0098	0,0037
Plastics	3,0	0,05	0,0005	0,0002
Copper	1,1	0,02	0,0002	0,0001
Mineral	6156,9	96,26	1,1023	0,4167
Sum	6396,2	100,00	1,1451	0,4329

By calculating the material intensities (e.g. t/m^2 or t/m^3) of the relevant material groups, extrapolations based on the floor area and the buildings volume can be made. When taking an estimated buildings service life of 80 years. It becomes apparent that in 2042 around 6400 tonnes of material will be available for the circular economy just from the single building mentioned in this example.

The majority, namely 96% of the buildings mass, is of mineral composition, such as concrete, tiles, bricks, and mortar. The second largest portion consists of around 140 tonnes of ferrous metals, which mainly come from reinforcement bars, radiators, and pipes. Not all of the ferrous metals can be recovered at the end, due to natural corrosion processes, which have and still are giving of fractions of the metals to the environment.

A relative small proportion of copper based materials are mainly found in electric wiring. The mass of copper for the electric wiring has been calculated from electrician bills, as part of the buildings refurbishment in the last decade. Around 0.2 kg/m^2 floor area of copper has been additionally incorporated into the building. This amount, minus the losses through corrosion and weathering processes, will become available after the buildings demolition. This amounts to over 1 t of copper that is currently in stored in the anthropogenic stock, which exceeds the natural concentration of copper in the earth's crust.

Timber based materials, mainly from the roof structure account for nearly 55 tonnes in this particular case. However, as the roof was constructed in the 1980ies, timber treatment has been used, especially for the structural elements, which nowadays is regarded as potentially harmful to humans and the environment.

With the current stand of standard 3D city models it is not possible to look inside a building, to identify the volume of inside walls or wall thicknesses for example. Wall thicknesses need to be taken from building typologies or estimated. The proportion of inside walls can be estimated, when taking standard values for the construction area. The Baukosteninformationszentrum (BKI) provides conversion factors for building areas and volumes, which are based on their extensive database. An example would be that the gross floor area translates to around 16-22% of construction area for single family dwellings. For multi-family dwellings this ratio translates to around 13 -16% [4]. These values have been checked within the case studies and coincide with data from the BKI.

3.2 Top Down Approach

The top down approach makes use of national statistics, such as production and demolition figures, just to name a few. A material flow analysis of mineral construction materials for the year 2012 has shown, that by balancing the in- and outputs of the system, the building stock has increased by 425 million tonnes of mineral material during that specific year. The total input of mineral materials for the same year was around 485 million tonnes. Around 60 million tonnes leave the system boundaries, which has been set as the German construction industry. Figure 1 shows the mineral flows within the German construction industry for 2012. The data for this particular case was taken from the Bundesverband Baustoffe – Steine und Erden e.V. [5].

The majority of recycled material content has been reused in the infrastructure sector, mainly road construction and earth works. Unfortunately statistics do not always differentiate between building construction and civil engineering activities. It is also questionable if using demolition waste for filling voids in road or landfill construction can be regarded as recycling. However, by using demolition waste for these applications, the primary material use can be reduced, without the requirement of a high energy input. However, one goal of the circular economy is to promote cascade use of materials and prevent a too high ratio of down-cycling.

3.3 Life Cycle Assessment

Once the material flows (life cycle inventory) are identified and the top-down and bottom-up analysis have been compared the next step is to conduct a life cycle assessment (LCA). The basis for life cycle assessment data will be the Ökobau.dat, a freely available German life cycle database, which contains data on most building materials used in the German construction industry [6]. With the aid of this datasets it will be possible to calculate indicators such as CO_2 emissions and embodied energy, which is the energy that is required to provide the materials. Also resource related indicators, such as the ADPelements (APDe), which purely rates the raw material consumption based on a reference material, can also be identified. The LCA will be based on international standards (ISO 14040 and ISO 14044) and will be in line with the criterias of the German building rating systems DGNB (German Sustainable Building Council) and BNB (Bewertungssystem Nachhaltiges Bauen).

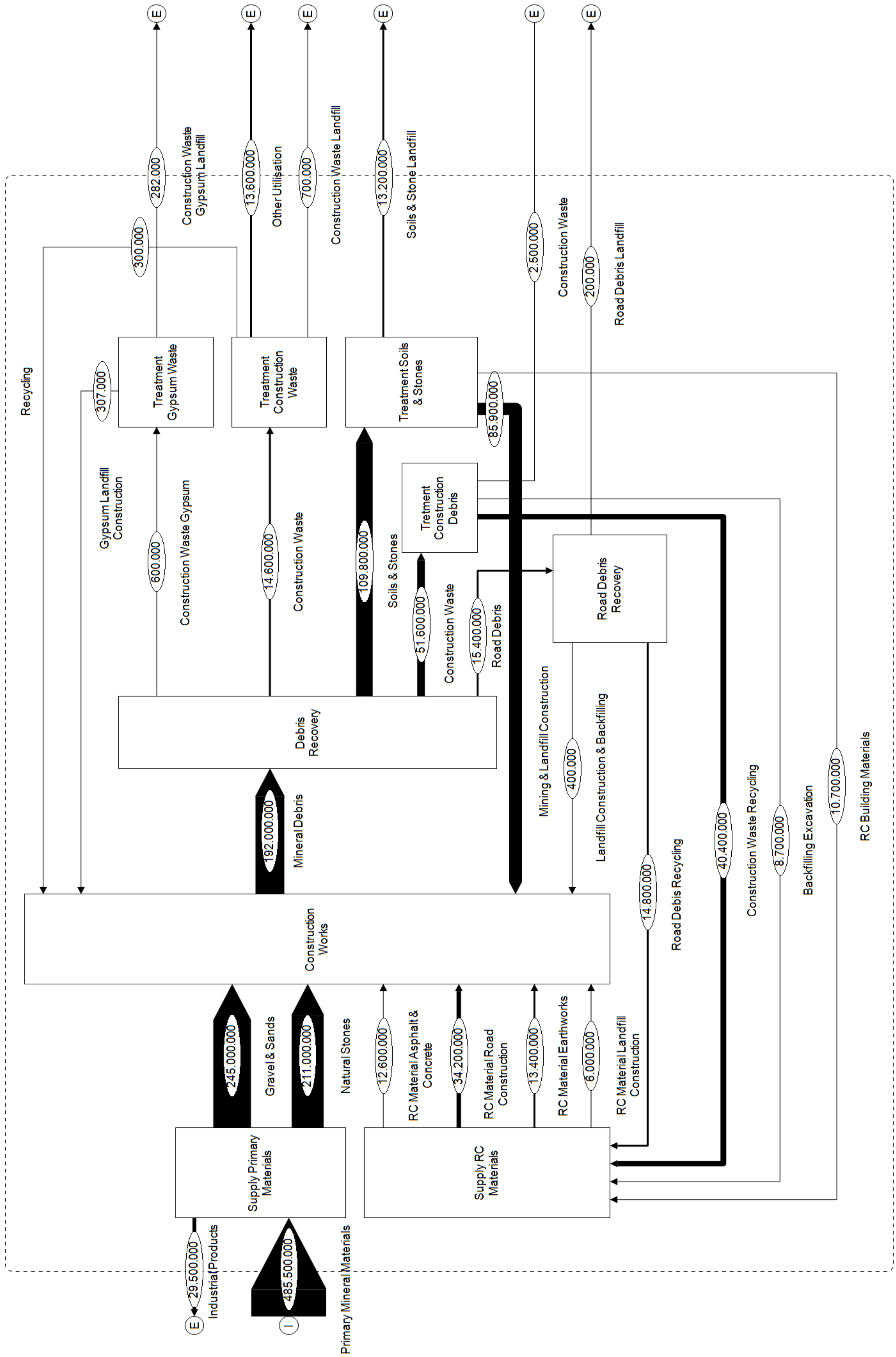

Fig. 1 Mineral material flows within the German construction sector for 2012 in tonnes/year (t/a) (Data from [5])

3.4 Potential Pollutants

A closer examination of potential pollutants that may be contained within the materials and demolition debris (e.g. asbestos, PCB) and the quality and purity of materials is also a very important factor for the integral model. These factors, among others, determine the future recycling options a material may have.

Especially buildings that have been constructed in the 1960s and 70s, that are now ready for retrofitting or demolition contain a variety of potentially harmful and hazardous substances that need to be properly recycled or landfilled. From experience, it will not be possible to calculate actual expected masses and concentrations of pollutants, as these need to be assessed on an individual building scale. Nevertheless, assumptions can be made on the probabilities that these substances arise based on the buildings age and area of application (e.g. building component). Buildings constructed after a certain date, after the use of materials containing potential pollutants have been prohibited, are likely not to contain these substances. Whereas buildings constructed before a ban on use has been pronounced may contain pollutants. Pollutants could have not just been introduced when the building was constructed, but also through renovation- and retrofit measures. An overview of selected pollutants found in buildings is shown in Table 2.

Table 2: Selected pollutants: Timespan of application in Germany

Pollutant	Examples of Application	Application		Prohibiting manufacture	Ban on use
		Since	Until		
Asbestos	Facade, cement additive, flooring, insulation	1920		1993	1993
Synthetic mineral fibres	Insulated building parts (e.g. walls, roof)	1900	1996	2000	2000
Pentachlorophenol (PCP)	Timber treatment			1989	1989
Polychlorinated biphenyl (PCB)	Seals, paints, plastics	1929		1989	1989
Polycyclic aromatic hydrocarbons (PAK)	Glue, tar products (e.g. roofing, asphalt)	1850		1970	
Lindane	Timber treatment	1950s		1984	2006

3.5 Separability

The separability of individual building components is also directly related to the quality of individual materials. As the connection between the individual layers of building components play a vital role in the way the material can be recycled or disposed of. The ability of a building component to be dismantled in an efficient way in the end of life phase sets the path for future recycling options and raw material flows. One way to address this issue in a way that is feasible for this model is to examine standard construction techniques and building components of the relevant age groups.

4. Application Potentials

Rising commodity prices, scarcity of raw materials, and the dependency on material exports are the main drivers for the development of this model. The developed model aims at analysing the material flows of the construction industry in Germany as well as the environmental effects that are caused by these flows. Upon completion the information can be used for the formulation of political goals and their verification. By identifying potential vulnerabilities, measures for system optimisation can be identified. The collection and evaluation of material flows provides a base for this analysis.

Demolition- and commodity companies, as well as recycling- and circular economy industries can gain an overview of potential future mass flows of construction related materials and pollutants (e.g. asbestos). Through the prediction of future demolition wastes, assessments of potential recycling flows and the quality of recycling material can be derived, as well as an assessment of the future need for additional locations for raw material mines, landfills and recycling systems. This information can also aid in the development of new recycling methods, if economically viable quantities of a particular substance or material are identified.

In Austria for example, material flow analysis has successfully been used in the development of the national environmental plan.

On the scale of the property owner, an assessment can be made on the exploration potential of their asset, which can be translated into economic benefits or burdens. Economic burdens can occur if potentially hazardous substances need to treated or deposited on landfills.

5. Further Discussion

It is important to trace resources, in this case building materials and its raw material components not only in a spatial dimension, but also over time. As an indication can be derived at what times materials and potential pollutants from buildings become available for further use, such as a substitute for primary raw materials, further treatment or disposal on landfill sites. In a further step, the gained information from this model can also be used to identify the radial distance where it is still feasible to use secondary raw materials as opposed to primary material resources within the individual material fractions.

In our built environment most elements represented by the periodic table can be found in element or in compound form. However, only a small fraction of material flows for individual substances have been identified on a national or international scale, let alone on a regional scale. Knowing these flows is however fundamental to create a model, which is looking at multiple flows of different materials. Steel alone, depending on the type consists of more than 20 individual elements, some of which may not be recovered through recycling.

6. Acknowledgements

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Development of a simple approach for applying LCA analysis to compare decentralized energy supply options for urban areas

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Summary

Nowadays, various options for the urban energy supply of the future in a decentralized context are being discussed. Many of them claim to be the ideal solution regarding climate change. For measuring ecological quality the Life Cycle Assessment (LCA) approach has proofed to be a reliable methodology in the past. This method is already common practice in Germany for comparing the ecological quality of single buildings, even of innovative concepts such as plus-energy buildings. However, the assessment of a total settlement seems to be rather complex as energy flows between buildings as demanders, their suppliers and storages have to be determined at first. In this paper a simple approach for applying LCA on the urban energy infrastructure will be presented. The approach consists of an energy flow model to calculate the electricity flows between electricity producers, consumers and a battery on a 15-minutes base. For modelling the consumers, i.e. the buildings, templates for several building types have been created that can be collected in a database.The developed model can be easily attached to the existing LCA approach for buildings so that a holistic analysis of energy and buildings in the urban context will be possible. In a scenario analysis it is demonstrated that the model is applicable for assessing a decentralized electricity supply on the settlement level. However, the assessment of heat flows is still reduced to a single building approach without any interaction. Nevertheless, various options exist for further development of the approach.

Keywords: Renewable energy, Decentralized energy supply, Settlement areas, Building demand, Life Cycle Assessment

1. Introduction

1.1 Decentralized energy supply strategies

Driven by the EU Directive 2010/31/EU [1], many strategies have been developed in recent years, to increase the share of renewable energy. Concerning renewable energy for buildings, many strategies focus on local production on the single building level. However, a decentralized supply on the settlement level could lead to more efficiency by using synergy effects.
An example is a photovoltaic system installed on a certain building. In this case it is an interesting option to share the produced electricity with the whole settlement in times, when it cannot be consumed by the building itself. A battery, accessible by the whole settlement, might even raise the share of a direct used energy so that less amounts of the produced electricity have to be fed into the public grid.
Furthermore a lot of options exist for renewable heat production in settlements. Solar thermal or geothermal energy sources can be used for single buildings, as well as for a whole settlement, distributed by a district heating network.
However, concerning the greater goal restricting climate change, it is not sufficient to focus only on energy flows for assessing the ecological quality of an energy system. Further system boundaries are necessary for analyzing the ecological impact of the energy production process and the ecological quality of the consumer i.e. the building. For this purpose the Life Cycle Assessment (LCA) methodology defined by ISO 14040:2006 [2] can be applied.

1.2 Life Cycle Assessment in the urban context

Applying the LCA method for urban planning has been discussed in the past. In many cases LCA is described as an element of an expanded urban metabolism framework [3], [4]. However, in the urban context the method has mainly been applied in practice only in the field of waste management [5], [6]. As the application of LCA for whole settlements is very complex [7], KOHLER has subdivided the whole urban built environment into the categories "*Buildings*", "*Infrastructure*" and "*Open Surface*" in order to simplify the assessment [8]. The following paper will propose an approach that can be applied on parts of these categories, which are related to the urban energy supply. The application of LCA for "*Buildings*" has already been established in Germany by including the approach into building certification systems. The first building certification system has been published in 2007, developed by the German Green Building Council and the former BMVBS. From this first certification system originated the DGNB (Deutsches Gütesiegel Nachhaltiges Bauen) system [9]. In the DGNB system the energy supply of single buildings is already included in the building LCA. However, only the total ecological impacts by the yearly final energy demand for heating are being calculated individually for each building design and added to the impacts by the manufacturing and dismantling processes of the building construction [10].
Due to the European Directive 2010/31/EU the energy efficiency development in the German building sector has led to plus-energy-building concepts [11]. As plus-energy buildings produce energy themselves, the LCA should also include the environmental impact by the produced energy flow. The implementation of the total fed-in electricity, produced by the photovoltaic systems for the first 20 years of the building lifecycle, is already being demanded by the DGNB system. As this amount of renewable energy replaces the amount, which would have been produced by the mostly non-renewable public grid providers otherwise, its environmental impact is added negatively on the LCA balance as a bonus [10].

A case study has been performed in former research on a plus-energy-building in Lüneburg, Germany. The results show that the environmental impact by the energy flows has a greater influence on the total balance result as the environmental impact by construction material related processes (see Fig. 1). This shows that all energy flows should be calculated diligently as they have a strong impact on the final result [12].

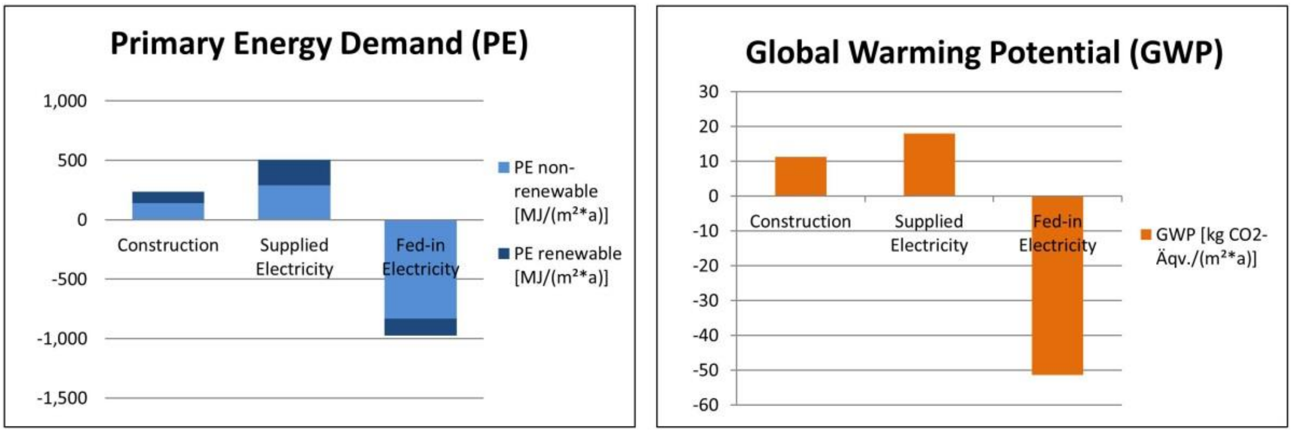


Fig. 1: PE Demand and GWP of the plus-energy-building in Lüneburg

When this former study was conducted a dataset for photovoltaic systems did not exist in the German database OEKOBAUDAT yet. The environmental impact of the material has been calculated according to the ecoinvent dataset. The impact of fed-in electricity has been described by applying the electricity mix dataset from OEKOBAUDAT negatively. In the following analysis presented in this paper the recently published photovoltaic dataset in OEKOBAUDAT has been utilized which includes also data for the fed-in electricity.

The "*Infrastructure*"category, as defined by KOHLER, contains the energy, water, transportation and communication network [8]. In this paper the assessment will only focus on the energy infrastructure. As described before, the existing LCA approach for buildings includes already the assessment of energy supply and energy production on the single building level. In the following model the energy flows of the different buildings in the settlement will not be assessed separately, if possible, as decentralized energy strategies for settlements often focus on grid effects. The energy LCA approach should be attachable to the existing building LCA approach in order to allow a holistic evaluation for both urban elements. An example is the analysis of the ecological impact of building refurbishment measures which result in a lower energy demand.
The assessment of the category "*Urban Open Surface*" (with elements such as trees or exterior lighting) will not be included in the first draft of the following approach.

2. Methodology

In this chapter the methodology behind the new energy infrastructure LCA approach is further described concerning system boundary, ecological database and energy flow model.

2.1 System Boundary

Figure 2 visualizes the system boundary of the combined energy and building LCA for the electricity supply and consumption of a settlement with a battery.

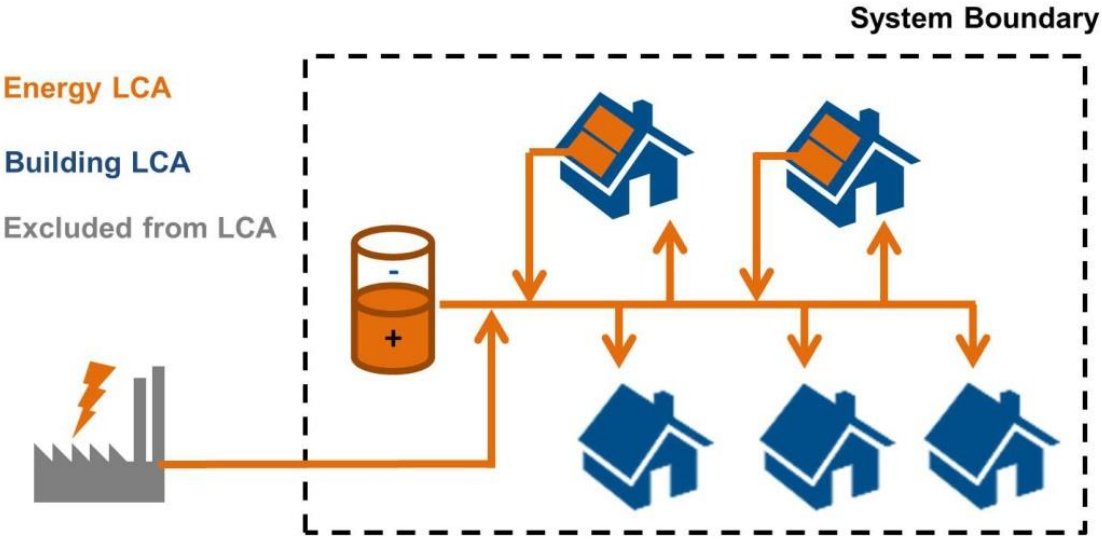


Fig. 2: System Boundary - Electricity supply and consumption

According to DIN EN 15978 the processes of an LCA approach should be allocated to separate modules which represent different phases of the building life cycle (see Table 1). The DGNB system has adopted this principle. However, it includes only a few modules in the assessment as apropiate data is currently not available for each module. The energy infrastructure approach will also take only the DGNB LCA modules into account in order to make the results adoptable to the existing approach for buildings. For combining the building and the infrastructure results, module B6 has to be excluded from the building LCA as it will be included in the new energy LCA approach. The production, exploitation and the credit of building technology will be shifted to the energy approach as well. Module D represents the environmental impact of recovery and recycling processes. If this value is negative it can be interpreted as an avoided environmental impact. In this case it has to be distinguished between processed that avoid the production of new material (i.e. reuse of construction waste) and processes that replace the production of energy (i.e. fed-in photovoltaic electricity).

Table 1: LCA Modules according to DIN EN 15978 and DGNB [13], [10]

	Production (A1-A3)			Erection (A4-A5)		Operation (B)							Exploitation (C)				Bonus (D)
	Resource Acquisition	Transportation	Production	Transportation	Installation	Utilization	Maintenance	Reinstallation	Substitution	Modernization	Energy consumption	Water consumption	Removal / Demolition	Transportation	Waste recycling	Disposal	Recovery / Recycling
Modules DIN EN 15978	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Modules DGNB LCA	x	x	x				x		x		x	x			x	x	x

Hence, the building LCA will only focus on construction material related processes, while the energy LCA covers all processes related to energy consumers, settlement internal energy producers and the energy flow itself. Concerning the external energy producers, such as power houses, only

the energy flow consumed by the settlement will be included in the LCA in module B6, but not the production or exploitation process of the power house building itself (see Figure 2).
DGNB defines as well which ecological impact factors and which consumed resources have to be included in the LCA as assessment categories:

Global Warming Potential (GWP)	[kgCO_2-Equ./(m²a)]
Ozone Depletion Potential (ODP)	[kgR_{11}-Equ./(m²a)]
Photochemical Ozone Creation Potential (POCP)	[kgC_2H_4-Equ./(m²a)]
Eutrophication Potential (EP)	[kgPO_4-Equ./(m²a)]
Acidification Potential (AP)	[kgSO_2-Equ./(m²a)]
Primary Energy Demand – non-renewable (PENRT)	[MJ/(m²a)]
Primary Energy Demand – renewable (PERT)	[MJ/(m²a)]

In order to make the new energy LCA approach combinable with the building LCA, the same assessment categories have been integrated in the new energy model.

2.2 Ecological Database

For calculating the ecological impact and the consumed ressources of an energy supply option the necessary ecological data has been included into the model. For this purpose the relevant data sets from the German Database OEKOBAUDAT [14] in the version of the Online-tool *eLCA v0.9.2 BETA*, developped by the BBSR [15] have been used.
All datasets are focused on a certain reference unit. Material related processes are usually defined per 1 kg or 1 m^3 while the impact of energy flows is usually descibed per 1 kWh respectively 3.6 MJ.

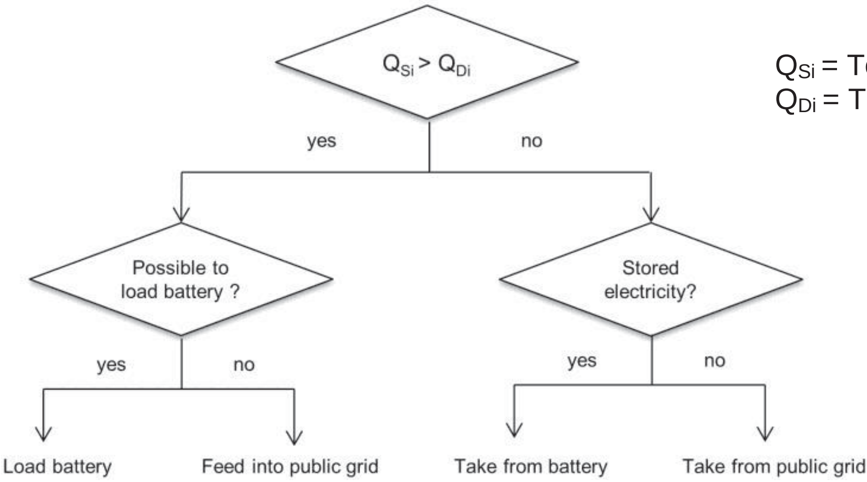
2.3 Energy flow model

In order to assess the energy flows, several types of energy producer and consumers as well as their interaction with a storage have to be implemented in the model. For this purpose two builiding templates have been created: A conventional building acoording to EnEV 2014 and a plus-energy building. Both buildings are newly built, single-family houses (160 $m^2_{\text{living area}}$) with a household of four persons. Both buildings are located in climate zone 12. The building templates differ in technological equipment and insulation:

The conventional building has been created according to the reference building of standard EnEV 2014 [16] and a representative real building defined by LOGA ET AL. [17]. The heat supply system consists of a condensing gas boiler. The total yearly gas demand is 8,967 kWh/a. A solar thermal tube collector (4 m^2) is supporting the hot water generation (1,612 kWh/a). The total yearly electricity demand of 5,596 kWh/a is provided exclusively by the public grid [18].

The plus-energy-building template represents the average building in the German plus-energy-building network founded by the BMUB [11]. Within one year the building produces more electricity than it consumes. Approximately 100 m^2 of the roof are covered with photovoltaic modules, which leads to an extremely large installed capacity of 15 kWp. Only energy efficient appliances are used in the household. The insulation of the building envelope (with λ= 0.03) is approximately 20 cm thicker than in the conventional building. Hence it has a lower heating demand which is covered by an electrical air-to-water heat pump (10 kW; COP: 3.1). The heat pump also delivers the necessary heat for creating hot water. In addition the building consists of a mechanical ventilation system.

Electricity can be produced in the settlement internally by photovoltaic systems or externally by a power house. For assessing the influence of a battery it is necessary to model the electricity flows in the settlement on a 15-minutes base. Hence, a year has 35,040 time steps in the model. For every time step t_i with i = 1…35,040 the following algorithm is run (see Figure 3):



Q_{Si} = Total internal electricity supply in t_i
Q_{Di} = Total electricity demand in t_i

Fig. 3: Battery algorithm

The storage capacity has to be set according to the total electricity demand of the settlement in the timeframe from 5 PM to 9 AM, in which no electricity is produced by the photovoltaic system in winter. The highest electricity demand during that period arises in the month of January with 10.9 kWh for one EnEV 2014 building and 11.7 kWh for one Plus-Energy-Building. The internal electricity supply by photovoltaic $Q_{Si,pv}$ has been integrated in the model by dividing the yearly electricity production of the generic OEKOBAUDAT photovoltaic module of 120.81 kWh/m^2 into 8,760 shares according to the hourly shares of the yearly solar radiation. As hourly values for the solar radiation the test reference year data (TRY) developed by the German Meteorological Service has been used [19]. Assuming a constant solar radiation during one hour, the hourly based values have been equally divided by four in order to create the 15-minutes based supply profile $Q_{Si,pv}$. Likewise $Q_{Si,pv}$ can be modelled individually for all 15 German climate zones.For modelling $Q_{Di,EnEV\ 2014}$ the BDEW (former VDEW) standard load profile H0 for households has been applied [20]. In order to create the $Q_{Di,plus\text{-}energy\text{-}building}$ dataset this H0 profile has been modified for the plus-energy building model [21]. This building has a reduced electricity demand for appliances by 23% and an additional electricity demand for the ventilation system, which can be calculated according to DIN 1946-6. The additional electricity demand for the heat pump has been modelled with the BDEW heat pump profile WP1 [20]. In addition to the standard load profiles, also monitoring data on a 15-minutes base for the consumption as same as for the supply process can be easily loaded into the model.
At the current state of the model it is not possible to compute the heat flows of a district heating system or a seasonal storage. Hence, the energy flows for heating and hot water have to be calculated separately for each building. Therefore it is appropriate to calculate the yearly final energy demand according to DIN V 18599 [22]. By applying this standard it is possible to integrate various decentralized supply and additional storage systems (such as geo- or solar thermal systems with buffer tanks). For most of them exists a dataset in OEKOBAUDAT. Likewise, it is very simple to implement the heat consumption and supply of buildings in the energy LCA

approach. The heat supply by combined heat and power (CHP) systems for a single building can be also calculated according to DIN V 18599. However, this leads only to monthly values for the CHP electricity production. For coupling the CHP electricity production with the battery it is necessary to find an appropriate distribution on a 15-minutes base. It is possible to develop hourly values by applying the simplified hourly-based approach of DIN EN ISO 13790. Assuming that the CHP system is always running constantly for at least an hour, the hourly values can be equally divided by four in order to create a 15-minute based CHP electricity supply profile [23].

3. Scenario Analysis

For testing the applicability of the developed energy LCA approach a scenario analysis has been conducted for a settlement with five buildings.

3.1 Scenario 1: 5 EnEV 2014 Buildings

The first scenario consists of five conventional EnEV 2014 Buildings. Figure 4 shows the results of the performed LCA in the categories Global Warming Potential and Acidification Potential. The two charts on the left show the material LCA for the building technology of all five buildings (50 years, 1 replacement), while the two charts on the right display their energy LCA:

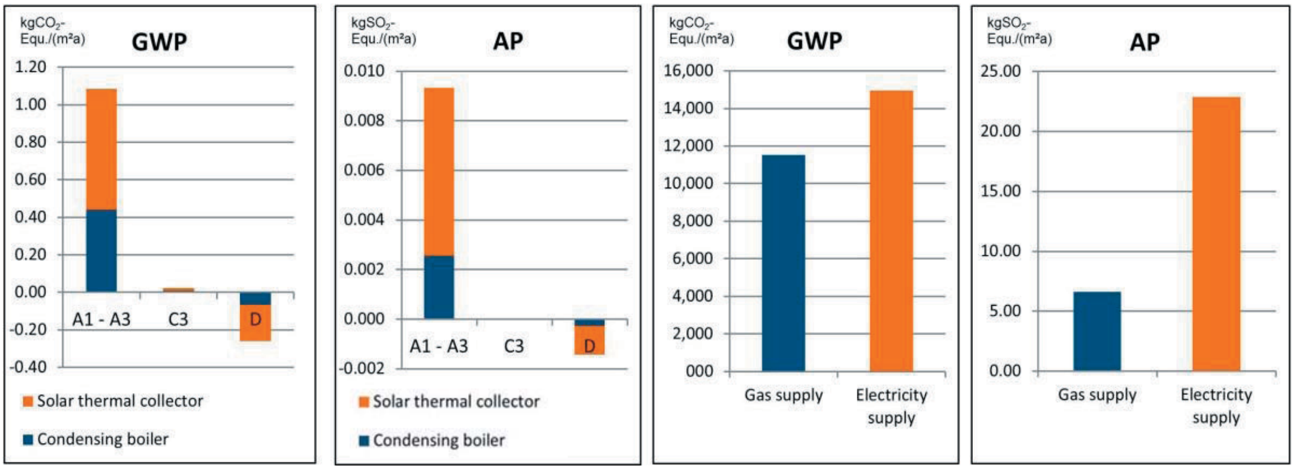


Fig. 4: Results LCA - Scenario 1

Concerning the material flows of the decentralized heat supply systems the solar thermal collector has the greater impact on the result, especially in the AP category (see charts on the left). As both systems consist mostly of metal related materials this can be explained by the larger material mass of the collector. As metal is recyclable both categories also get a bonus in module D. The influence of the materials on the overall LCA result is almost neglectable compared to the ecological impact caused by the energy flows (see charts on the right). Here, the amount of externally supplied electricity has the greatest impact on the result. Therefore, the intention of Scenario 2 is to reduce this amount by replacing two EnEV 2014 buildings with Plus-Energy-Buildings and the installation of a battery.

3.2 Scenario 2: 3 EnEV 2014 Buildings, 2 Plus-Energy-Buildings, Battery

For applying the LCA approach on Scenario 2 the electricity flows between photovoltaic system, battery and buildings have to be determined at first by the energy flow model. Figure 5 visualizes these electricity flows for the total settlement with an installed storage capacity of 56.1 kWh. The direct used electricity describes the amount of decentralized produced electricity that can be used directly by buildings or for charging the battery.

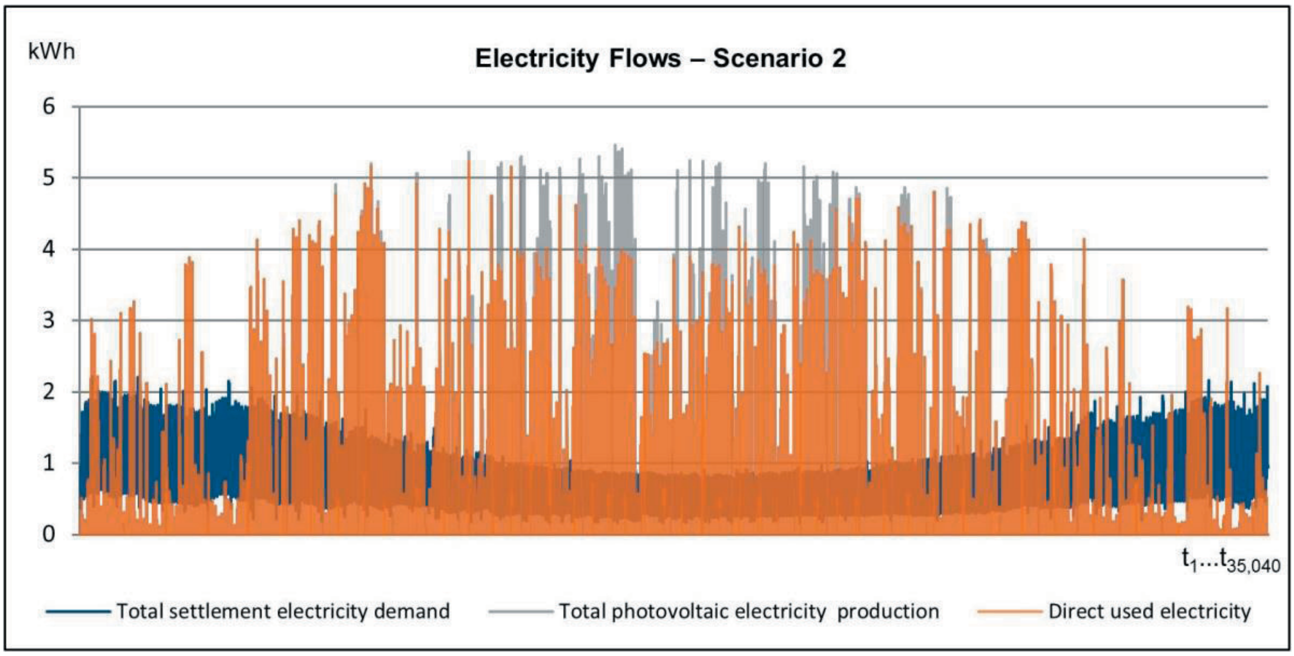


Fig. 5: Electricity flows - Scenario 2

Integrating two plus-energy buildings and the battery results in a decreased external electricity supply from 27,980 kWh (Scenario 1) to 8,565 kWh (Scenario 2). Consequently this improves the LCA result, shown for the GWP category in Figure 6 (right chart).

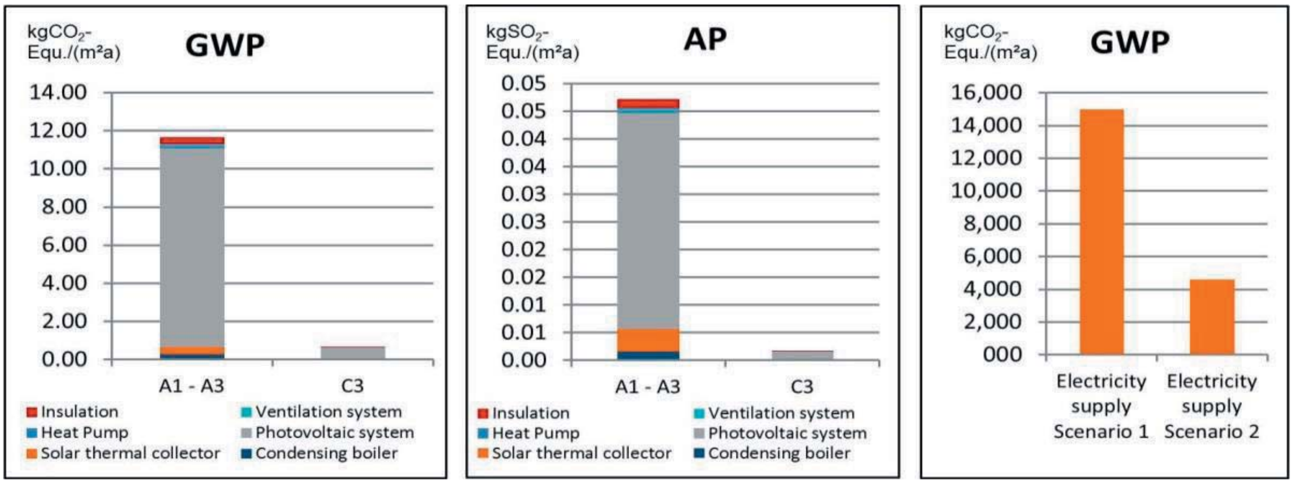


Fig. 6: Results LCA - Scenario 2

The charts on the left side and in the middle show the material LCA for the building technology of 3 ENEV 2014 and 2 Plus-Energy-Buildings. This ratio of 3:2 has been chosen for reaching a high share of direct used electricity (approx.65 %). Hence feeding-in huge amounts of produced electricity into the public grid can be avoided which is regarded to be unsustainable on the long run. Module D has been excluded from the material LCA as the recently published photovoltaic dataset in OEKOBAUDAT (which has been used here) also contains the bonus for fed-in electricity. The insulation has been included as it leads to the lower heating demand of the Plus-Energy-Buildings but has an additional impact in modules A and C. Both charts show that the photovoltaic system has the greatest additional impact, which can be justified with the much larger electricity savings (by factor 100 in GWP) in the energy LCA (right chart). The material flows of the battery could not be included into the LCA as no matching dataset exists in the OEKOBAUDAT. For further studies existing data in other databases such as ecoinvent could be adapted and implemented into the model.

4. Conclusion and Further Outlook

The aim of this paper was to show the results of a simple approach for performing LCA on energy infrastructure that could be combinable with the existing building LCA approach in order to allow a holistic analysis of energy and buildings in the urban context. The conducted scenario analysis showed that it is possible to analyze an electricity grid with decentralized electricity supply by photovoltaic systems and batteries at current state. It should be noted, that not all necessary ecological data (material flows of the battery or CHP unit) can be found in OEKOBAUDAT. Also the immense bonus in module D of some datasets should be analyzed critically. The assessment of heat flows is still reduced to a single building approach without any interaction between buildings and suppliers via a heat network. Hence, an additional simple model for estimating flows, distribution losses and storages for district heating would be a valuable addition to the model. Likewise also the feed-in process of heat, produced by the solar thermal collector, into this grid, could be assessed. Not only the ecological but also the economic quality of an energy supply option should be assessable in order to establish it in the market on the long run. A methodology for that could be the Life Cycle Costing (LCC) analysis. An LCC analysis could be attached to the developed approach as the regarding inventory is the same as in the developed LCA approach. Therefore, the already existing amounts of material or energy would be connected with their monetary indexes instead of their ecological impact factor. As former research showed, that simplified LCA approaches concerning building technology can lead to significant deviations from holistic approaches with broader system boundaries [24] a further step would be a pilot phase on existing settlements. Likewise, also inaccuracies of the energy flow model could be identified and a general LCA benchmark for assessing the ecological quality of various decentralized energy supply options could be developed.

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Development of the LCAbyg tool: influence of user requirements and context

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Summary

A 2014 Danish governmental building strategy introduced sustainability of buildings as one of five focus areas for the future political work within the sector. Subsequently, a wide range of sector stakeholders were involved in developing a tool to assess the life cycle environmental impacts of buildings. Compliance with the guiding LCA principles and frameworks was important to developers and stakeholders alike. However, extensive participation from stakeholders also generated a multitude of additional user related requirements for the tool to balance and prioritise within the restrictions of time and cost. The commissioning party and the politically related context of the tool development thus showed to greatly influence the process and the outcome.

Keywords: tool development, stakeholder participation, life cycle assessment, policy making, contextual influence

1. Introduction

The LCAbyg tool was launched in spring 2015 as a new life cycle assessment (LCA) tool for quantifying environmental impacts from a building's life cycle under Danish conditions. Almost a year of development went before the launch and further updating is scheduled to take place in the coming years with a version 2 to be released before the end of 2015. Being a strategic political project, involvement of the many interests within the building sector was a key element during the development. Thus, stakeholders participated from all levels of the pre-use building life cycle, from the regulatory bodies to the contracting companies.

This paper presents how the work on a national building LCA tool for the construction sector has been balanced between practical prerequisites, user requirements and general LCA principles of transparency and comprehensiveness. The paper furthermore discusses the underlying contextual factors driving the development of this kind of tool.

1.1 The Danish LCA tool development

Leading up to the year 2000, a larger scale research project at the Danish Building Research Institute resulted in the development of a building LCA tool named BEAT (Building Environmental Assessment Tool) [1]. In the years after the development, the tool was extensively used for national research purposes and publications to document the environmental profiling of buildings and building materials. The database incorporated in the tool was created with the EDIP methodology and founded on empirical data from the building manufacturing industry in Denmark [2]. The database was specifically created for the tool and thus very representative for the actual technological processes used in the production of building materials.

Even though the BEAT tool was used in research at the time, it was never fully adopted by the national building sector for use in the design, planning or regulation of building activities. The incentives for evaluating the environmental impacts of a building were missing, other than those environmental aspects related to e.g. indoor climate, energy consumption or similar which were controlled within the framework of the existing building regulations. With time, the tool's database was outdated, partly because the EDIP methodology ceased to be updated and partly because of a lack of funding for the continuous updating and development of the database.

Following the recent decade of the European Union's growing focus on eco-design, life cycle thinking and resource efficiency, environmental sustainability in the building sector has gained increased interest in Denmark. Life cycle assessment is perceived as an important methodological tool to quantify the emissions and resource uses associated with a building's life cycle. A 2014 governmental building strategy introduced sustainability of buildings as a focus area alongside four other areas for the future political work within the sector [3]. The development of a new LCA tool for buildings was an initiative within this strategic focus area, and the LCA tool project itself was subsequently commissioned and funded by the Danish Energy Agency. The Danish Building Research Institute carried out the work of developing and programming the new tool, LCAbyg.

A project monitoring group was established of approximately 25 stakeholders from all levels of the building design phase (building product manufacturers, architects, consulting engineers, building contractors and developers) as well as the planning and/or regulatory body (e.g. Environmental Protection Agency; Copenhagen Municipality; Ministry of Housing, Urban and Rural affairs). The monitoring group participated in two workshops prior to the launch of the software tool; one being held as part of the project start-up (May 2014) and one being held just before the monitoring group received the test version of the tool. A group of seven stakeholders volunteered to test the tool and reported on the user experience for final adjustments before the final tool launch. Subsequently, two additional workshops have been held to evaluate the tool and the process and to outline the content of the second version of the tool.

1.2 Standards and guidelines behind building LCA tools

Even within Europe, building LCA tools are very different in terms of e.g. system boundaries and environmental indicators [4]. This heterogeneous picture of tool characteristics can probably partly be attributed to the broadness and generality of the ISO 14040-14044 frameworks within which many earlier released tools are developed [5][6]. The ILCD handbook (2012) from the EU Joint Research Centre provides specific guidance on a range of these general LCA topics [7]. However, at the same time the ILCD guidance is in some areas (e.g. choice of environmental impact categories) countered by the sectoral specific standards EN 15804 and EN 15978 [8][9]. The EeBGuide

(2012), a European research project, addressed this inconsistency between the guidance and standards and developed metrics and operations guidance for LCA of construction projects and for the creation of LCA tools [10].

The European standards, EN 15804 and EN 15978, cover life cycle assessment of construction works and support a harmonised approach for defining, structuring and calculating the building life cycle impacts. Although not as comprehensive as the ISO 14040-14044, they provide a framework for LCA that is specific for buildings. For instance the ISO 14044 calls for a comprehensive set of impact categories but suggests no set of indicators, whereas the EN 15804 and EN 15978 provide a list of impact categories to be covered, but omit some areas of probable environmental concern within most goal and scope definitions of building LCAs, e.g. potential toxicological impacts.

The EN 15804-15978 standards provides a common reference for describing building life cycle stages in modules A-D (see Figure 1). Several European countries already have programmes for environmental product declarations (EPDs) for building products adhering to the EN 15804 as a standard, and the relevance of these EPD programmes might increase in the future due to the Basic Requirements of the Construction Product Regulation [11] [12]. An LCA tool's compliance with the framework of the EN 15804-15978 can thus be seen as a way of ensuring a broadly accepted structure of the life cycle stage calculations. Furthermore, compliance with the EN15804-15978 can be seen as a potential gateway to an increasingly integrated European market of EPDs trough the mutual recognition carried out in the ECO Platform organisation of EPD programme operators.

Life cycle stage modules		Sub-module	
Building life cycle information	Product stage	A1	Raw material supply
		A2	Transport
		A3	Manufacturing
	Construction process stage	A4	Transport
		A5	Construction, installation process
	Use stage	B1	Use
		B2	Maintenance
		B3	Repair
		B4	Replacement
		B5	Refurbishment
		B6	Operational energy use
		B7	Operational water use
	End of life stage	C1	Deconstruction, demolition
		C2	Transport
		C3	Waste processing
		C4	Disposal
Supplementary information	Benefits and loads beyond the system boundary	D	Reuse-, recovery-, and/or recycling potentials

Fig. 1 Modular structure of building life cycle stages as presented in EN 15978

The EN 15804-15978 structural framework for defining the building's life cycle has been a pivotal point in structuring the LCAbyg tool. Furthermore, basic LCA principles of transparency and comprehensiveness, as introduced in the ISO 14040, were sought applied in the functionalities of the tool. However, by inviting a wide range of sector stakeholders to participate in the development of the tool, additional user related requirements for the tool gained importance in the context of the development. Thus, a wide range of favoured points and principles needed prioritising in the inevitable limitations by practical prerequisites of time and cost.

2. Topics for prioritisation in the tool development

2.1 General LCA principles

General LCA principles of transparency and comprehensiveness were key areas of concern in the LCAbyg tool development process, for developers and stakeholders alike. More specifically, in the context of LCAbyg, the terms refer to the following identified topics, where choices had to be made in the development of the tool:

Transparency:
1. LCIA database incorporated in the tool
2. Documentation format of the building assessments carried out with the tool

Comprehensiveness:
3. Environmental impact categories assessed
4. Life cycle stages included in the calculation
5. Level of inventory detail for the building assessments carried out with the tool

2.2 User requirements

Moreover, a range of user specific requirements were introduced by the broad stakeholder monitoring group. The following user requirement topics were a part of the tool development:

6. Predefined building elements to ensure speed of tool operation
7. Evaluation of results (e.g. hotspot, alternatives)
8. Import of EPDs
9. Provide access to calculation engine of tool to facilitate further, external development (e.g. BIM communication)
10. Representative to Danish conditions
11. Compliance with potential DK or EU regulatory requirements

An additional, more general, user request of simplicity was also put forward for the tool development. In this regard simplicity refers to a range of subthemes, e.g. user interface and results interpretation. The immediate contradiction to the principle of comprehensiveness is dealt with in the discussion.

3. The LCAbyg tool – implemented solutions

The following describes how and to which degree the concerns and requirements expressed in the 11 topics for the LCAbyg tool were fulfilled. Each topic refers to an ideal solution where the concern/requirement is fully met in accordance with the framework of standardised LCA principles or the stakeholder preferences. The implemented solution describes the actual result of the development process, i.e. the outcome of the prioritisation that took place and the resulting functionality in the LCAbyg tool. Additional comments explain details of tool functionality and/or how the different topics may be interlinked.

Topic 1: LCIA database

Ideal solution: A database that includes both EPD's and generic data, preferably Danish data for products produced and processes taken place in Denmark and for use at different levels of study (screening, simplified, detailed)
Implemented solution: Since there is no national Danish database available the database is based on generic German database Ökobau
Comment: Manual import of EPDs by user possible. Using the German Ökobau database brings lack of transparency of the data, since the description of the datasets in Ökobau are all in German and the LCAbyg tool does not include direct link to the description of each dataset.

Topic 2: Documentation format
Ideal solution: Full report as suggested by e.g. the EeBGuide project [10]
Implemented solution: Version1: Only functional equivalent and total LCIA results. Version 2: To be decided, but will include more information than version 1
Comment: Must balance full transparency and thus comprehensive reporting with users not familiar with LCA concepts for the reporting itself.

Topic 3: Environmental impact categories
Ideal solution: More comprehensive than those put forward by EN 15978, e.g. more of the ILCD recommended indicators [7]
Implemented solution: From EN 15804: global warming potential (GWP), ozone depletion potential (ODP), acidification potential (AP), eutrophication potential (EP), photochemical oxidant creation potential (POCP), abiotic depletion potential (elements – ADPe, and fossil - ADPf). Based on EN 15804: Primary energy use (total, i.e. sum of renewable and non-renewable), use of secondary materials as fuel (total, i.e. sum of renewable and non-renewable)
Comment: A consequence of the choice of database where impact categories are aligned with the EN 15804

Topic 4: Life cycle stages
Ideal solution: By choice, all modules A-D of EN 15978 (results of module D presented separately)
Implemented solution: Only those where scenarios and data exists: A1-A3: from generic data, B4: based on Danish service life table, B6: based on data for Danish energy supply, including the possibility for forth casting of future energy scenarios, C3-C4: from generic data
Comment: Due to the use of the German database, data cannot always support representative scenarios for Danish conditions, e.g. regarding end-of-life scenarios and building products with electricity intensive production process.

Topic 5: Level of detail
Ideal solution: Facilitating all three types of study as recommended in the EeBGuide [10]; screening, simplified and detailed
Implemented solution: Program developed primarily for simplified studies.
Comment: It is possible to conduct detailed studies with the program, although time consuming due to manual entries of EPD data and structuring data of additional life cycle stages

Topic 6: Predefined building elements
Ideal solution: Comprehensive library of building elements and building types
Implemented solution: Version 1: Limited library of two building types and the included elements Version 2: Enlarged library of building elements
Comment: Examples that can be modified seem to be a key parameter for architects to use tool in the design process where LCAs are performed on a screening level

Topic 7: Evaluation of results
Ideal solution: As implemented except for the stakeholders wishes for the possibility of showing the results as single score.
Implemented solution: LCIA results available for breakdown of: life cycle stages, building elements, product groups. Normalisation and comparison of alternate projects is possible.
Comment: Possibilities for analysing results was highly prioritised in the development to ensure that user understands how and where in the building life cycle impacts are allocated. There is the possibility for normalised results based on normalisation factors from 1995, but no method for single score was implemented.

Topic 8: Import of EPDs
Ideal solution: Automatic import of verified, EN 15804 compliant EPDs as part of the program's library of building products
Implemented solution: EPD data is imported by the user and data must be entered manually. Responsibility of EPD data quality thus lies on the user
Comment: This approach balances uncertainties about the quality of EPDs with the user convenience of finding EPDs as part of the program database

Topic 9: Calculation engine access
Ideal solution: Not clarified
Implemented solution: Not implemented, but considered for future versions
Comment: Fulfilment of this user request could lead to expanded use of tool to communicate with e.g. BIM or thermal models

Topic 10: Representative to Danish conditions
Ideal solution: Danish conditions for data and scenarios
Implemented solution: German data for the production of materials (A1-A3) and the end-of-life (C3-C4), Danish data for energy in use stage (B6)
Comment: Production technology behind data is probably similar to Danish conditions. Energy background data for production will not be representative, especially the electricity mix

Topic 11: Compliance with potential regulatory requirements
Ideal solution: Not clarified
Implemented solution: Partly compliant with the EN15978, although simplified in terms of life cycle stages included and impact categories assessed
Comment: Most stakeholders are expecting that this standard's framework will increase in importance on a European level for the building sector

4. Discussion

4.1 Balancing requirements of transparency and comprehensiveness

Only in few cases do the implemented solutions in the LCAbyg tool correspond to the ideal solutions for fully meeting general concerns of transparency and comprehensiveness as well as user requirements. The trade-offs are to some extent due to the limitations within the background database, where only few database options proved feasible to the project. The Ökobau database has the main advantage that it is focused on compliance with the EN 15804-15978 standards and thus follows the modular structure and the recommended impact categories actually used in the sector. The Ökobau database contains generic production data as well as product specific EPD data. A challenge in this regard can be seen in the emerging alienation of stakeholders towards the legitimacy and validity of the LCIA results presented by numerous EPD programmes [13]. However, this transparency issue is rooted in the EPD practice based on Product Category Rules (PCR) communication formats and not as such in the Ökobau database itself.

Another limitation regarding comprehensiveness of life cycle stages is due to the fact that generic, representative scenarios are still not in place, e.g. when it comes to the construction activities or the maintenance cycles of different materials. Research work to complement the development of these scenarios is needed in order to fill this gap. This is in line with the EeBguide's analysis of European building LCA tools, concluding that all identified tools fail in assessing the complete building life cycle as they each only include a selection of life cycle stages [4].

4.2 Balancing the user requirements

The same analysis of the European building LCA tools reports that each tool is developed under a specific context and with a pre-defined goal in mind, servicing the need of some stakeholders but not all of them [4]. In the development of LCAbyg, we identified a clear risk that too many potential user groups and needs are taken into account. Such a situation may result in a tool that attempts to serve too many needs but that lacks resources to provide easy-to-use functionalities to do so. Nevertheless, a key objective of the tool development was to involve and engage a wide range of stakeholders from the building sector in the creation of a tool, and the tool development process did experience committed participation from all stakeholders. Thus, the tool development created a valuable discussion forum where common interests and prioritisations were clarified between stakeholders.

The prevalent user request for a tool that is simple to use refers to two different aspects. As an aspect of user interface friendliness, intuitive design is in focus. As an aspect of system simplifications, the request is in direct conflict with the scientific aim of comprehensiveness. As long as the comprehensiveness of the life cycle system is difficult to obtain, as expressed in previous sections, simplifications of the life cycle system are carried out on a reference background not known. An example from the LCAbyg tool is how the A4 module (transport to the building site) is not yet part of the assessment in LCAbyg due to practical programming limitations within the project. For some materials and building elements, this life cycle stage could prove influential on the LCIA profile [14]. Until there is a possibility to include this life cycle stage in the program calculations, the user must be informed, if not of the relevance of the life cycle stage, then at least of its existence. To meet this kind of deficits in the program, a layman instruction for the tool itself and for LCA on buildings in general was elaborated as part of the project [15].

4.3 Context – drivers for the LCA tool development

Apart from the balancing of user requirements and principles of transparency and comprehensiveness, the context within which the LCAbyg tool is created has left a large fingerprint on both the process and the functionalities implemented in the tool. Induced by a political strategy, the LCAbyg tool serves as a means to educate and involve the sector on the topic, and furthermore to prepare for potential regulatory requirements in the future, e.g. evaluation of embodied energy use of constructions. Such a requirement has been debated as part of the potential introduction of voluntary sustainability classes in the building regulations.

Examples of this context and the related effects on the LCAbyg tool and the development process are:

- Work commissioned as part of policy development → free tool, many stakeholders involved
- Past bad experience on in-house database → externally operated database
- Expected broadness of user group → thorough LCA and tool guidance supplementing the tool
- Potential future use for voluntary sustainability class → tool supported by many different stakeholders
- Energy Agency as commissioning party → tool includes modelling of dynamic energy scenarios for building's use stage

Other driving forces for developing an LCA tool could be commercial, educational or research interests. The resulting outcomes of the different drivers would thus probably be very much varying in terms of functionality and user interface, also to accommodate the different groups of users planned for the tool. Hence, from the point of view of the LCAbyg development experiences, there is no one-size-fits-all LCA tool for the building sector, which explains the multitude of different building LCA tools in operation internationally.

4.4 Stakeholder participation

As part of an official, although not regulatory, area of policy, the legitimacy of the tool to the broad stakeholder group was of paramount importance to the project initiator, the Danish Energy Agency. Thus, the selection of involved stakeholders was meticulously carried out to ensure all sector interests represented. Naturally, this broadness of special interests presents certain obstacles in the sense that it is not possible to please all interest based wishes. However, in the LCAbyg development we experienced a large degree of understanding towards this from the stakeholders. Their expressing interest or areas of concern and having it noted down for further potential use in the development, resulted in a general atmosphere of support for the tool development and the way of engaging the stakeholders. Furthermore, for us as tool developers, the stakeholder comments were oftentimes valuable perspectives not previously considered.

Guiding principles on participatory model development highlight the need for planning for an iterative and adaptive process [16]. However, the time constraints of the LCAbyg development project significantly limited the possibilities for reiterating project goal and project measures. Thus, the outline of the most important decisions regarding software type, background database and LCA system boundaries were already in place at the first workshop for the stakeholders. There was sufficient understanding for these context specific conditions from the stakeholders, possibly helped by the project group's thorough disclosure of methods and reasoning behind the choices.

In total, the comprehensive extend of the stakeholder participation resulted in a successful tool development process although the product itself may not fulfil the lot of the scientific and user related requirements put forth in the process. However, when stakeholder group validation and verification counts as a metric of success in participatory modelling [16], the LCAbyg certainly find its value in gathering the attentive support from a vast range of the national building sector.

5. Conclusion

The LCAbyg tool adds one to a seemingly growing number of digital tools aiming to assist in the evaluation of the potential environmental impacts from a building's life cycle. Thorough guiding principles for LCA tool development can be found within several existing standards (e.g. ISO

14040-14044, EN 15804-15978) and projects (e.g. EeBGuide). However, experience from the development of the LCAbyg illustrates how the specific context and the participating stakeholders influence the outcome of a tool development project considerably.

Compliance with the guiding principles and standardised frameworks was important to developers and stakeholders alike. However, an extensive participation from stakeholders generated a multitude of additional requirements for the tool to balance and prioritise within the restrictions of time and cost. For instance, enhanced completeness of the building life cycle was forfeit to accommodate other features related to the user interface.

The contextual outline of the LCAbyg tool development was exactly to engage the national building sector as part of a political strategy towards increased use of LCA. Thus, the success of the project must not entirely be measured on the functionalities of the tool and the degree to which the tool complies with standards and guidelines. Bringing stakeholders together to discuss the way forward for a common national tool is in this regard seen as an imperative first step towards a robust tool solution for the entire sector.

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Diversification of construction projects by implementing collaboration and information sharing tools

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Summary

In many of the construction projects, multicultural project teams have become a "common practice" and teams work together towards achieving the set goals. To coordinate the activities of the projects accordingly, all parties involved in the project have to work collaboratively and share information. The need for formalization in the form of computerized solutions for collaboration and sharing of this information has increased resulting in implementation of other Information Technology solutions that are stand-alone, meaning the systems are either installed on individual computers or a group of computers. Contrary to these systems, Web Integrated Information System promise to be less expensive, easier to implement, promote collaboration and capability to share information within construction projects. The purpose of the study is to investigate the effectiveness of Web Integrated Information System as a tool that improves collaboration and information sharing within construction projects in South Africa.

Keywords: Collaboration, Information Sharing, Construction Project, Web Integrated Information System.

1. Introduction

Projects set up goals that need to be achieved by using temporary resources; including human resources and often the resources are interchangeable from projects to projects (Frimpong, 2003). Within construction projects, management activities are usually undertaken by construction industry professionals, engaged singularly or as part of consulting and/or contracting organisations operating in the construction industry The complexity of construction projects has resulted in project teams consisting of a wide range of specialist professionals (architects, engineers, quantity surveyors, planners, project managers, etc.) collaborating in the achievement of its successful completion (Taiwo, 2007).

According to Hargis (2008) the crucial element of project teams is that they frequently share data or information that promotes preservation of knowledge, which is more essential for construction projects. However due to the flexible and short-term nature of construction project activities and processes, project teams formed are usually dismantled upon the completion of the projects (Bannister & Remenyi, 2005). As a result, lessons learnt on many construction projects are often lost when the project teams are disbanded at the end of a project and the parties move on to new projects (Latham, 1994).

Construction projects are phased with the lack of information, and amongst the prevalent information there is a lack of quality, health and safety information. The absence of information results in construction projects re-inventing the wheel and repeating past mistakes (Taiwo, 2007). The situation is further complicated by the fact that there are few mechanisms for capturing and sharing the new knowledge gained through the duration of the projects (Latham, 1994). In crafting the culture of collaboration within construction projects, collaboration efforts have been addressed by the development of rapid global Information Technology (IT) solutions (Emmitt & Gorse, 2007).

Information within the construction projects identifies the resulting product, initiates and controls the activities required for construction (Björk, 2004). Taiwo (2007) asserts that “controls and standards such as quality, health and safety have become an aspect that is nearly followed by media and is interested by many different parties such as the community, authority, owners”, so the information has to be available as interest in quality, health and safety has grown about construction project (CIDB, 2014).

Lack of quality, health and safety information amongst other prevalent information, results in re-invention of the wheel and repetition of past mistakes (Taiwo, 2007). The situation is further compounded by the fact that there are few mechanisms for capturing and sharing the new knowledge gained on construction projects (Latham, 1994). In crafting the culture of collaboration within construction projects, collaboration efforts have been addressed by the development of rapid global Information Technology (IT) (Emmitt & Gorse, 2007).

Some construction projects in South Africa have developed these global IT solutions referred to as the Web integrated Information Systems, which are integrated Information Systems that are comprised of quality and health safety systems among others that are accessible through the internet. Web Integrated Information System also promises to promote collaboration and information sharing. However, regardless of the technological advancements collaboration and information sharing is about the people and the organisational culture (Turban, Aronson, Liang & Sharda, 2011). This has been evident in several IT solution implementation challenges reported, that key to solution success is people either rejecting the system or not using it effectively to help realization of the system’s intended benefits. Heeks (2003) further asserts that the majority of projects are failures. Hence the purpose of the study is to investigate the effectiveness of Web Integrated Information System as a tool that improves collaboration and information sharing within construction projects in South Africa.

2. Methodology

Conducting a research involves exploring a phenomenon to increase knowledge, systematically gather facts and solutions to an enquiry which is undertaken within a framework of a set of philosophies or approaches called research methodology (Kumar et al., 2010). A research methodology enables the researcher to identify a theory, in which the research should be undertaken, the approach in which data is obtained and arranged to yield the findings (Saunders & Tosey, 2013). This study attempts to provide an understanding of the effectiveness of Web Integrated Information System as a platform for improved collaboration and information sharing efforts within construction projects, therefore the study applies positivism as a worldview to underpin it. Positivism in this study supports the development of the research background, its nature and knowledge (Saunders et al., 2009). Using the positivism philosophy the study focuses on observations that are quantifiable and makes use of statistical analysis (Saunders et al., 2012).

A quantitative approach concentrates on the confirmatory stages of the research cycle, that is, the formulation of a hypothesis and the collection of numerical data to test this hypothesis. A quantitative approach includes experimental and non-experimental research strategies (Maree & Pietersen, 2007: 149).The focus of this study is a non-experimental research strategy survey research. This study evaluated the effectiveness of Web Integrated Information System as platform for improved collaboration and information sharing efforts by collecting numerical data and using a questionnaire. The study involved “explaining a phenomenon by collecting numerical data that are analysed using statistical based methods” (Leedy & Ormrod, 2005).

Surveys were distributed to Web Integrated Information System users as; surveys are easy to distribute, inexpensive and convenient for gathering data from large numbers of people spread over wide geographic area and reduces chances of evaluator bias because the same questions are asked of all participants many people are familiar with surveys (Leedy & Ormrod, 2005). Survey’s measure the current status, opinions, beliefs and attitudes by questionnaires or interviews from a known population (McMillan & Schumacher, 2001).

To address the purpose of this study, purposive sampling was applied for the survey research. Purposive sampling is a non-parametric sampling method in which the researcher purposefully identifies participants as a source of data (Creswell, 2003), samples with a purpose in mind and predefines a group of one or more that results persuaded from (Cohen et al., 2007) in this study purposive sampling was applied by selecting project teams that use Web Integrated Information System. To evaluate the effectiveness of Web Integrated Information System as a platform for improved collaboration and information sharing efforts project teams involved within construction projects that use Web Integrated Information System were identified based on the criteria below:

- Team members should have been exposed to the Web Integrated Information System for quality, health and safety.
- The construction projects had to be based either within the Gauteng and the Limpopo province of South Africa, so that researcher could access and collect data within the time constraints of the study.
- The study excluded project teams that use standard alone systems, non–complaint to quality, health and safety.
- Project teams had to follow similar process in terms quality, health and safety, only those within this category who were willing to participate.

All participants involved in a research study must be informed and approve of understanding the risks, potential benefits, procedures and alternatives (Wendler & Grady, 2008). The selected areas of study were two construction projects based in the Gauteng and Limpopo Regions of South Africa. Three project teams were selected from respective projects. Project Team 1, 2 and 3 were selected to address the purpose of the study and represented the entire construction project. To ensure elicitation of accurate information from appropriate participants that are parallel to the study objectives, analysis was done in three units (project teams) that use Web Integrated Information System for quality, health and safety. The project teams using quality defect include the following members, Defect Initiators, Package Quality Assurance Engineer, Lead Discipline Engineer, Project Manager, Planning Engineer, Engineering Manager and Quality Manager and for, health and safety project teams include Incident Initiators, HS Practitioners and HS Managers.

A total of 50 questionnaires were distributed as follows; 16 to the Project Team 1; 17 to the Project Team 2; and 17 to the Project Team 3. Out of 50 questionnaires 40 questionnaires were returned. The 14 questionnaires were from Project Team 1, 13 from Project Team 2 and 13 from Project Team 3. Of the fifty distributed questionnaires to the participants from the three identified project teams, forty were returned. Questionnaires were distributed by hand and email to participants as per unit of analysis section. Participants were given time to complete the questionnaire in their own time and return completed questionnaires to the researcher. The researcher constantly reminded the participants to complete the questionnaires and eventually forty participants completed them.

To bring order and understanding to the data collected, analysis and interpretation is required. Data analysis requires creativity, discipline and a systematic approach (Taylor-Powell & Renner, 2003). The data collected from questionnaires was analysed by using SPSS (Statistical Package for Social Science) computer software. SPSS is a Windows based program that can be used to perform data entry and analysis and to create Tables and graphs. Collected questionnaires were first checked for errors and unanswered questions and a data sheet was then created in Microsoft Excel (For record keeping and future references). Each question was uniquely numbered and data was organized where each response was given its own column. The responses from each Likert-scale questions were given a separate row, the responses “strongly agree,” “agree,” “Uncertain,” “disagree,” and “strongly disagree” were each put into separate columns and coded 5,4,3,2, and 1 respectively. The data was then exported to SPSS and the following statistical procedures including One Sample t Test, Cronbach’s Alpha test were used to support reliability of the survey and Correlation Analysis were used to analyse the data.

According to Saunders et al. (2009), researchers have to obtain formal Research Ethics Committee approval for their proposed research, including their data collection methods, prior to organisations granting them access to conduct research. The Tshwane University of Technology Faculty Research Ethics Committee approved the ethics clearance for this study and the researcher provided the Information leaflet which describes ethical standards governing the research. Participants familiarised themselves with the information leaflet so they could decide whether to participate in the study or not. The researcher did not ask the participants to sign but the researcher assumed that completion and returning the questionnaire was acceptance. Those who did not return the questionnaires were assumed to have refused consent.

3. Results

3.1 Response Rate

Response rate is the percentage of employees who actually complete the questionnaires and return them to the researcher (Stangor, 2011). A total of 50 questionnaires were distributed to the participants and only 40 were completed and returned. The response rate was 80% and therefore acceptable for the study. The results will be presented in the same sequence that the questions were asked on the questionnaires.

3.2 Demographics

The sample was made up of 40 participants. Of the participants, 67% were males and 33% females.

3.3 Highest Education Level Attained

The highest proportion of the participants had diplomas (42%), followed by those that had degrees (28%), and those with postgraduate degrees (18%). 10% had certificates and only 2% had Matric.

The One Sample t Test was applied to Web Integrated Information System responses, using a five-point Likert scale, with five (5) as strongly agree, one (1) as strongly disagree and three (3) Neutral, the applied midpoint was three (3) for questionnaire responses. The results on the perception of the participants and t-test values testing the hypothesis that the mean ratings are equal to the midpoint of the scale (3) are presented below

3.4 Question: What do you use Web Integrated Information System for at the construction projects?

The results show that all the uses of Web Integrated Information System had means ratings that were significantly higher than the midpoint of the scale since the p-values for the t-test were less than 0.05 and the means are higher than 3. This means that the participants agree with these uses of Web Integrated Information System. “Tracking and reviewing the status of incidents and (4.15), “Collaborating with project team members to finalize incident and defects” (4.10), “Sharing of incidents and defects reports with project teams” (4.05). “Capturing flash reports for incidents and defects” (4.03) had the lowest rating as a use of Web Integrated Information System in construction project.

3.5 Question: Which of the following collaboration and information sharing challenges have you faced while in a construction project?

The results indicate that the biggest challenge is that project information is kept in silo (company based) systems (3.92 out of 5), fragmented project teams (3.53), processes that are based on complex interrelationships (3.51) and (3.45) for lack team work. The mean ratings were significantly higher than the mid-point of the scale (3) since all the p-values were less than 0.05 (significant level). Thus, the participants were agreeing with these presented factors as the challenges they are faced with that hinder knowledge sharing in construction projects

3.6 Question: Do you consider the following as barriers to successful collaboration and information sharing?

The results indicate that the biggest barrier to successful collaboration and information sharing “Lack of support to enable participants to share relevant information” (3.92 out of 5), followed by “The inability to automise some of the operations” (3.82), and “Lack of manpower, capital and awareness of the latest technology” (3.46). The mean ratings were significantly higher than the mid-point of the scale (3) since all the p-values were less than 0.05 (significant level). Thus, the participants were agreeing with the barriers presented to them.

3.7 Question: Do you perceive Web integrated information system as an effective tool for collaboration and information sharing?

The overall perception on Web Integrated Information System as being an effective tool for collaboration and information sharing, had an average rating of 4.23 out of 5. The mean is significantly higher than midpoint of the scale (3) since the p-values for the t-test of 0.000 is less than 0.05. This means that the participants were overall satisfied with Web Integrated Information System as being an effective tool for collaboration and information sharing.

3.8 Question: What are the benefits of using Web Integrated Information System for collaboration and information sharing?

“Reduced travel time” (4.48 out of 5) cited as the highest rated benefits of using Web Integrated Information System for collaboration and information sharing followed by “Information is accessed from a central repository” (4.43), then “Increased awareness of overall project activities” (4.18) and “Increased collaboration efforts” (4.08). All the benefits had mean ratings significantly greater than the mid-point of the scale since all the p-values were less than 0.05 and thus the participants agreed with the benefits of using Web Integrated Information System for collaboration and information sharing.

4. Discussion

4.1 Demographics and Highest Level of Education

This section of the questionnaire explored the participants’ profile, these included, gender, education and experience. The section revealed that the majority of the participants (32%) have experience working within construction projects 0 – 5 years, 42% have been in the project space for 5 – 10 years, 10% for 10 – 15 years, 5% for 15 – 20 years and the remaining 11% for over 20 years. The construction projects had a mixture of males and females, with the male gender dominating with 67% and 33% females. The education levels of the project participants varied from matric to post graduate, with matric holders being 2%, certificate holders being 10%, the majority 42% of the participants held diplomas, 28% had bachelor degrees and only 18% percentage have studied towards the postgraduate level.

These results indicate that Web Integrated Information System users have completed formal educational and at least obtained university entrance; educational background informed the study that the users didn’t need additional training such as literacy or numeracy training and that users were capable of attending Web Integrated Information System training; The experience gained by Web Integrated Information System users in construction project informs the study that that users had been exposed users construction project processes that may or may not involve the use of IT systems such as Web Integrated Information System.

4.2 Applications of Web Integrated Information System within construction projects

The results indicate that participants are using Web Integrated Information System for its original intent, participants prior to Web Integrated Information System captured incidents on manual systems or company based and project sites information was kept as quarantined. The majority of participants (87.5%) indicated that they use the system to collaborate with project teams to finalize incidents and defects followed by reporting on incidents and defects. This indicates that systems reports might be extracted in events such as project meetings to discuss the amount of incident and defects that may delay or hinder the projects.Web Integrated Information System use also indicates that (82.5%) of participants track and review incidents.

This aids projects to track culprits with unresolved issues and give penalties if required, though the system was implemented for capturing incidents and defects management, the results indicate that lesser amount of users, use the system for capturing incidents and defects management. It may simply mean that because of the positions of the individual, there has not been a need for them to capture any incident or defect, but simply report on the matters. Lastly sharing of incidents and defects reports with project teams indicates that lesser usage of this application of Web Integrated Information System, this however should not be of concern, as not all users of the system will require or extract reports while on the projects. However should the reports be required, they must be readily available

4.3 Collaboration and Information sharing challenges users have faced while in construction projects

The challenges were based on literature (Caballero et al., 2002; Higgins, 2007; Xu & Tsa, 2012), and participants were expected to respond based on experience within the construction industry. Even though there has been an increase in the number of IT systems introduced in construction, an overwhelming number of participants tend to have experienced challenges of project information kept in silo or company based system, these challenges indicate that though projects belong to the client, there is a lack of information sharing if there is no system that is implemented to cater for all project teams from different companies (Brown et al., 1996). The lack of information sharing also impacts on team work as teams are fragmented. Lastly (45%) of the participants did not agree with interrelationship based on complex relationship as the participants have sufficient education and experience working in construction.

4.4 Barriers to successful collaboration and information sharing

Participants agree with literature (McCook, 2002; Mehra et al. 2006) that barriers to successful collaboration and information are mostly experienced due to the lack of support as there is a lack of IT expert within construction sites. The majority (62.5%) also identified inability to automate some operations is a barrier. This is due to complex process within construction projects. In the cases where construction projects are short term, it is for this reason that there is a lack of capital investment in the latest technology projects, projects would rather invest in infrastructure than technology.

4.5 Perception of Web integrated information system as an effective tool for collaboration and information sharing?

From the responses the study reveals that participants (50%) perceive the Web Integrated Information System to be effective for collaboration and information sharing within construction projects. The participants were overall satisfied with Web Integrated Information System as being an effective tool for collaboration and information sharing. This indicates that the system enables users to share information and collaborate as required by construction projects.

4.6 Benefits of using Web Integrated Information System for collaboration and information sharing

Organizations that collaborate and share information tend to experience benefits such as centralized information and knowledge preservation. In establishing the benefits of using Web Integrated Information System participants rated the given benefits in the questionnaire. Participants (92.5) rated access to information from a central repository as the most experienced benefit, the findings are in concurrence with the existing literature on these benefits (WIPA, 2014; Ahmad et al., 1995;

Latista, 2013) and affirms the body of knowledge that Web Integrated Information System also provides the benefit.

Reduced travel time is another benefit that Web Integrated Information System users agreed to be experiencing, this is beneficial as most construction companies are not based at construction sites and the ability to have access to the site system through the web reduce turnaround time by having to complete tasks from any location and not having to travel to construction site. Participants also indicated to have increased collaboration efforts and increased collaboration efforts, this means teams are working together and promoting awareness of overall project activities due to information availability from a central repository.

5. Conclusion

The primary research question that the study sought to address was to investigate the effectiveness of Web Integrated Information System as a tool that improves collaboration and information sharing within construction projects in South Africa. Web Integrated Information System was critically analysed as a tool for collaboration and information sharing and the benefits and barriers of Web Integrated Information System were highlighted. The conclusion drawn was that, project teams within construction projects are fragmented and to successfully deliver a project, team work is required from project teams. There is a lack of support for project teams specifically when trying to share information easily and flexibly. The challenge for these projects is collaborating and sharing of information across all project teams. In providing proper tools for collaboration and information sharing construction, projects have benefits such as increased overall awareness of the project.

While IT is a solution within construction projects, the use of silo systems is producing isolation of information. The introduction of Web Integrated Information System has promised to eliminate challenges faced by the construction project. The findings of this study confirmed that Web Integrated Information System is indeed an effective platform for improved collaboration and information sharing efforts in construction projects. Therefore construction projects are recommended to implement Web Integrated Information System as an effective platform for improved collaboration and information sharing. Also it was identified that organizations that have integrated systems tend to experience benefits such as improved operational performance and internal management methods, teamwork across all functions, motivated staff, and reduced inter-functional conflicts due to audit trails and cost reduction due to less travel time.

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Documenting sustainable business practices of housing companies: Sector-specific supplement to the German Sustainability Code (Deutscher Nachhaltigkeitskodex, DNK)

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Summary

Because of the persistence of residential buildings, housing companies traditionally manage their housing stock in a sustainable way and take on social responsibility.

The housing sector was quick to identify the importance of sustainability reporting. Therefore, the *GdW Bundesverband deutscher Wohnungs- und Immobilienunternehmen* (Federal Association of German Housing and Real Estate Enterprises) developed a sector-specific concept and published corresponding guidelines for housing companies. This approach resulted in the initiative to also publish a sector-specific supplement to the German Sustainability Code (Deutscher Nachhaltigkeitskodex, DNK), which emphasizes the distinctive features of the housing industry concerning their strategies and goals. Their business processes (mainly housing stock management) are opposed to those of other sectors.

The paper covers the importance of sustainability reporting in the housing and real estate sectors. Because of this importance the process of establishing standards for the reporting of sustainable activities and strategies of housing companies is described.

Keywords: German Sustainability Code/ Deutscher Nachhaltigkeitskodex, housing industry, sustainability reporting

1 Introduction

Sustainability as a model for the housing and real estate industry is nothing new. Acting economically, ecologically and social responsibly has been characteristic of the housing companies' strategies for decades. Thus most of the companies now feel obligated towards the principle of sustainability. This is expressed in the way in which residential property is managed and residential and urban districts are further developed with perspective. It is an expression of the striving to maintain and further develop property values and equally to take into account the social needs of the residents.[1]

Operating sustainably does not mean forgoing conventional returns. Quite the opposite: it is becoming clear how much sustainability and the orientation towards social and ecological standards are significant as an economic standard for corporate success. The reverse is also true: a healthy economic basis is an important prerequisite for operating in tune with the environment and recognised social values.[1]

Economy, ecology and social affairs stand aside one another as equals and account for one another. It took a long time for this formula to be accepted in society. This consensus was built up over a period of years.[2]

Table 1: Dimensions of sustainability in the housing and real estate industry[3]

Life cycle phase	Economic dimension	Ecological dimension	Social dimension
Property planning and construction	Cost-saving construction and planning: • affordable • quality concious • life cycle-orientated • Support of local and regional economy	Ecological construction and living: • energy-efficient construction • resource-saving construction • low-emission construction • space-saving construction • quiet living	Appropriate housing supply in new developments: • participation of residents/ neighbours • family-friendly living • elderly-friendly living • Housing supply of specific target groups • residential environmental design
Maintenance and utilisation	Building management: • operating costs management • maintenance management • administration management • customer management	Resources and environmental management: • Reduction of resource consumption and waste from user households ○ in building maintenance/ use ○ in internal company processes ○ at cooperation partners	Social management: • occupancy policy • offer of services • cooperation with local initiatives • participation and resident communication • personal development and employee qualification
Conversion, alteration, modernisation or restoration	Affordable restoration, modernisation and conversion: • affordable • quality concious • life cycle-orientated • Support of local and regional economy • property upgrading	Ecological alteration, restoration and modernisation: • improvement of energy efficiency • improvement of the use of other resources • resource-saving alteration/ restoration • minimisation of noise exposure	Appropriate housing supply in inventory: • participation • adaptation of living space to user requirements • residential environmental design
Removal or demolition	Cost-efficient Removal and demolition: • Removal and demolition management	Ecological recycling: • component recycling • material recycling • brownfield recycling	Social responsibility • Participation in the removal • socially acceptable process organisation in demolitions

1.1 Sustainability strategy of the housing industry

The housing and real estate sector is no longer a recipient of housing policy, as it was in the years of housing shortages. Today this industry is economically interesting and, at the same time, environmental and climate protection policy has its focus on the housing industry:

- 30 per cent of the entire energy demand in Germany are allotted to real property,
- 30 per cent of all resources are used for the operation, construction and demolition of properties,

- 40 per cent of greenhouse gases harmful to the environment are released through the utilisation of real property.[1]

Concerning housing stock, 21 per cent of final energy consumption is used on space heating in households. 15 per cent of CO_2 emissions are created in the heating of living spaces and water heating. A third of this is used in rented properties of the multi-storey residential buildings, whereas two thirds is used in owner-occupied or rented one and two-family homes.[4] The proportion of CO_2 emissions of the apartments operated by GdW companies is at around 2 per cent of the German energy-induced emissions.[5][6]

In the past the industry has met the demand for minimising CO_2 emissions: the housing industry already exceeded the German Kyoto goals ahead of time by 2005.[7] Thanks to the high modernisation efforts the GdW companies have been able to reduce the CO_2 emissions of their housing stock by around 35 per cent since 1990.[1]

In order to achieve a cross-social sustainable status a set of sustainability goals and fields of action can be defined (cf. Table 1) and be transferred to the housing and real estate industry directly. Since they cover the topics “property planning and construction”, “maintenance and utilisation”, “conversion, alteration, modernisation or restoration” and “removal or demolition”, the listed goals and fields of action encompass the whole life cycle of residential buildings.[8]

It is indisputable that housing companies have developed concepts for sustainable handling in almost all of the fields listed in Table 1. Particularly in the core business, the management and further development of residential property, many housing and real estate companies use a sustainable thought process. The range of topics underlines the extent to which the housing and real estate industry has dealt with sustainability. This process began in as early as 1992, when the *AGW Arbeitsgemeinschaft großer Wohnungsunternehmen* (Working Group of Large Housing Enterprises) created guidelines for a sustainability strategy. In this respect the housing and real estate industry has lead the way nationally in terms of sustainable handling.[1]

1.2 Sustainability management: a new cross section function for housing and real estate companies?

The housing and real estate industry, due to its company purpose, the associated resource requirements and the proximity to the people that live in the residential properties, is particularly affected by the European and German sustainability strategy.

Key topics such as 'energy and climate', 'raw material industry' and 'demographic change' particularly affect the housing and real estate industry. But the topics of 'health' (home as a third healthcare location), 'education' (local educational partnerships) and 'social integration and migration', which are emphasised in the German government's progress report on the sustainability strategy, have developed into important topics for the housing and real estate industry over the past few years.

Recent years’ achievements in the fields of climate and resource protection, in city and urban development and in social management show how comprehensive the measures of many housing and real estate companies are in their regional and local sphere in allowing various aspects of an ecologically, economically and socially sustainable development to flow into their actions.

In the face of societal change processes and the importance that the topic of sustainability now has in politics and other industries, the housing and real estate industry has to self-critically check if sustainability is being 'lived' in a certain way, but not professionally and efficiently implemented in all processes in terms of a management function.

Exemplifying sustainability as a matter of course is one thing, being able to believably prove it in every dimension is another. In future it will be necessary to better integrate sustainability aspects into strategic instruments – such as portfolio management, maintenance and modernisation planning, operating cost management – than in the past. This is a new dimension of how housing and real estate companies deal with the topic of sustainability. It goes well beyond CSR reports and reports on urban and social returns as successful approaches.

The housing and real estate industry has the best qualifications to keep leading the way in terms of sustainability with a clearly focussed sustainability strategy. With consistent sustainability management as a cross-section function it will also become clear where more sustainability is necessary for the future of the industry.[1]

2 Reporting frameworks as a possible starting point for a housing economy sustainability report

The number and level of maturity of company sustainability reports has dynamically developed over the past few years.[9] The increasing prevalence of sustainability reports is the result of international as well as national reporting initiatives that have advanced the standardisation and quality assurance of company sustainability reporting in the recent past.[10] On an international level, particularly the sustainability reporting system of the Global Reporting Initiative (GRI) as well as the Corporate-Social-Responsibility (CSR) reporting concept of the European Housing Network (EURHONET/ EURHO-GR) are to be quoted. With the German Sustainability Code, an instrument for sustainability reporting was created in 2011 on a national level particularly for the financial and capital markets.

2.1 GRI reporting framework

The GRI framework for sustainability reporting guide provides information in a structured form about

- the fundamental components of a sustainability report
- content aspects of the representation of company sustainability in the areas of 'strategy and analysis', 'governance', 'working practices', 'human rights' and 'ecological performance'

The GRI reporting framework includes quantitative and qualitative indicators for the representation of sustainable handling in the various topics. These indicators can be used across industries according to GRI. Furthermore, an addition to the general GRI framework tailored to the construction and real estate sector, the Construction and Real Estate Sector Supplement (CRESS) has existed since 2011.[11]

2.2 EURHO-GR reporting framework

Alongside the general framework of GRI, the CSR reporting system of the EURHONET (EURHO-GR) based on the public and social housing industry can be used as a basis for sustainability reporting in the housing and real estate industry. The EURHONET is a fusion of public and social housing organisations from numerous European countries. The network follows the goal of exchanging experiences and promoting the initiation of future-orientated projects in public and social housing companies. As part of EURHO-GR a catalogue of quantitative and qualitative indicators were developed, which are recommended to the member organisations as a basis for CSR reporting.[12]

2.3 The Sustainability Code

Additionally, the *RNE – Rat für Nachhaltige Entwicklung* (Council for Sustainable Development) developed the German Sustainability Code (Deutscher Nachhaltigkeitskodex, DNK). This provides proof of sustainable actions in the areas of corporate strategy, process management, environment as well as society and is primarily aligned towards sustainability reporting for the financial and capital markets. In order to fulfil the Code companies create and publish a so-called declaration of conformity on a voluntary basis. In this the agreement of the corporate policy with the Code criteria is to be qualitatively described or a missing agreement to be explained in free text. The reference to already published reference documents, particularly an extensive sustainability report, is expressly recommended in this.[13] In addition to the individual Code criteria, additional 'performance indicators' are given in the guidelines for the German Sustainability Code, that are taken from the reporting systems of GRI or EFFAS30 and are to serve as greater comparability. Companies can carry out additions using recognised industry-specific performance indicators. Numerous sector-specific indicators can be reported per code criterion.

The main goal of the German Sustainability Code is to reset the framework conditions for economic success. It creates comparative frameworks to enable competitors to compare sustainability performance using standardized minimum requirements. Mainstreaming is facilitated through the public access to the provided information using the Code’s database. The Code aims to lower transaction costs and achieve standardization through capital market actors. It also fosters an environment for market driven rewards by addressing new investor groups, promoting investment opportunities and channeling capital flows into sustainable business models.[14]
The standard of the Sustainability Code covers four main areas (strategy, process management, environment, society) comprising 20 criteria altogether. Additionally it is backed up by 16 EFFAS and/ or 28 GRI performance indicators leaving the opportunity to also add sector specific indicators. The specific requirements of the housing and real estate sectors are met by the first sector supplement, developed by *GdW Bundesverband deutscher Wohnungs- und Immobilienunternehmen* (Federal Association of German Housing and Real Estate Enterprises) together with the *RNE – Rat für Nachhaltige Entwicklung* (Council for Sustainable Development) and the *AGW Arbeitsgemeinschaft großer Wohnungsunternehmen* (Working Group of Large Housing Enterprises). The appendant indicators cover certain topics as investment intensity per square meter living space, reduction of CO_2 since 1990, percentage of energetically reconstructed or barrier-free accommodation units, expenditures for social projects etc.

The reporting scope of descriptive texts covering any criterion or key performance indicator should lie within the range of 500 to 2.000 characters respectively. Companies report on the extent to which they meet the Code criteria (“comply”), or provide plausible explanations as to why they are not reporting on certain criteria ("explain"). Thus the Code can be readily applied by companies and organizations of all sizes and legal forms. [14]

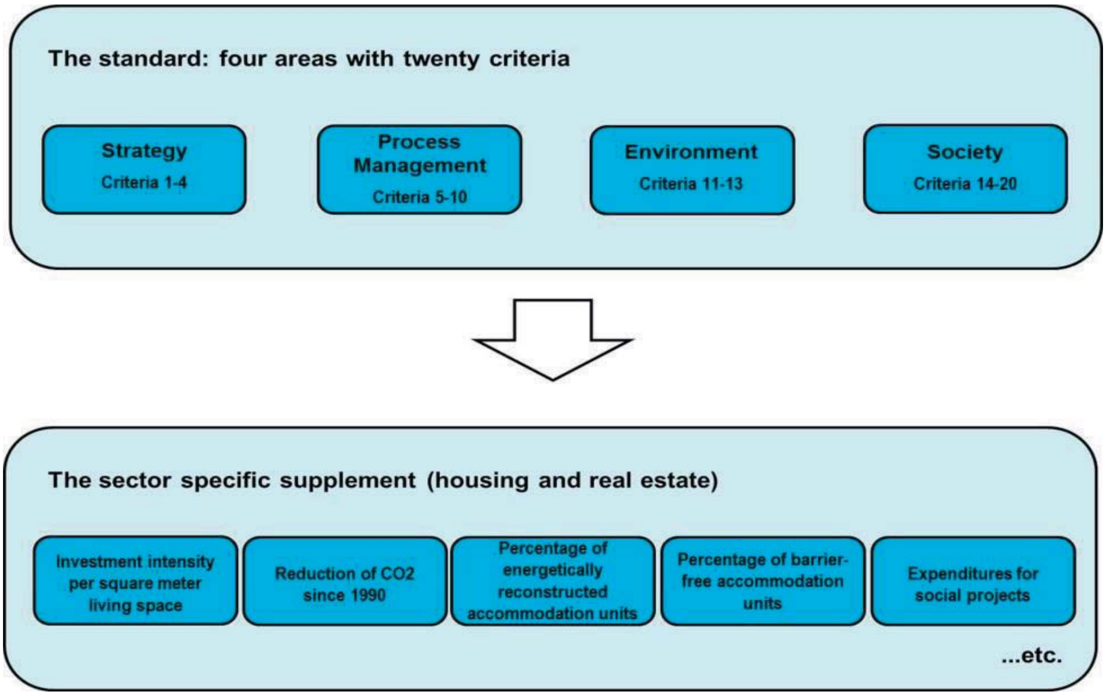

Fig. 1 The Sustainability Code – Criteria and sector specific supplement. (Adapted from [14])

3 Sustainability reporting in the housing and real estate industry

The future success of housing and real estate companies will greatly depend on a sustainable management strategy. The consistent implementation of sustainability goals along housing and real estate economy added value processes, but also in particular the communication of sustainability goals and sustainability services for housing and real estate economy stakeholders, will increasingly influence the competitiveness of housing and real estate companies in the future. With this in mind, a stakeholder-orientated sustainability reporting becomes increasingly important also for companies of the housing and real estate industry.[15]

To an increasing extent, the economically, ecologically and socially sustainable running of housing and real estate companies is documented and communicated. Alongside the sustainability qualification of new constructions – e.g. according to the seal of quality for the support *of NaWoh - Nachhaltigkeit im Wohnungsbau* (Sustainability in Residential Building)[15][16] – a sustainability report for communicating sustainable actions to housing economy stakeholders is suitable, which contains the most important economic, ecological and societal effects and services of the r housing/ real estate company being reported on.[17]

Due to the importance of effective sustainability reporting the housing and real estate industry has been working on this topic for a number of years already. In order to be able to establish sustainability reporting far-reachingly, the agreement on uniform report standards as well as industry-wide applicable report content is necessary. Whether and to what extent existing reporting frameworks and designs were to be seen as sufficient and functional in their current form for corporate sustainability reporting first had to be checked. There are subareas that are not or only partially taken into account by existing approaches. With this in mind, with regard to reporting concepts and recommendations particularly by GRI/ CRESS and EURHO-GR, a specific design was first to be developed for sustainability reporting of companies of the housing and real estate industry. This should also mean working towards a further standardisation and quality assurance of housing and real estate economy sustainability reports.

According to this goal, in 2013, the *GdW Bundesverband deutscher Wohnungs- und Immobilienunternehmen* (Federal Association of German Housing and Real Estate Enterprises) created a guide[15], with which housing and real estate companies are given action recommendations for agreement on the fundamental frame conditions of the reporting organisation as well as the determination, structuring and firm establishment of the report structure and (possible) report content in housing and real estate economy sustainability reports. A particular emphasis was on the definition of significant sustainability figures that were also comparable across the industry. Interested companies can orientate themselves around the recommendations of a practical implementation of figure-supported sustainability reporting with guidelines tailored to the specific requirements of the housing and real estate industry. The firm establishment of report content (particularly sustainability-related figures) as well as the selection of emphases took place along the lines of individual company visions, models and strategic goals.[8]

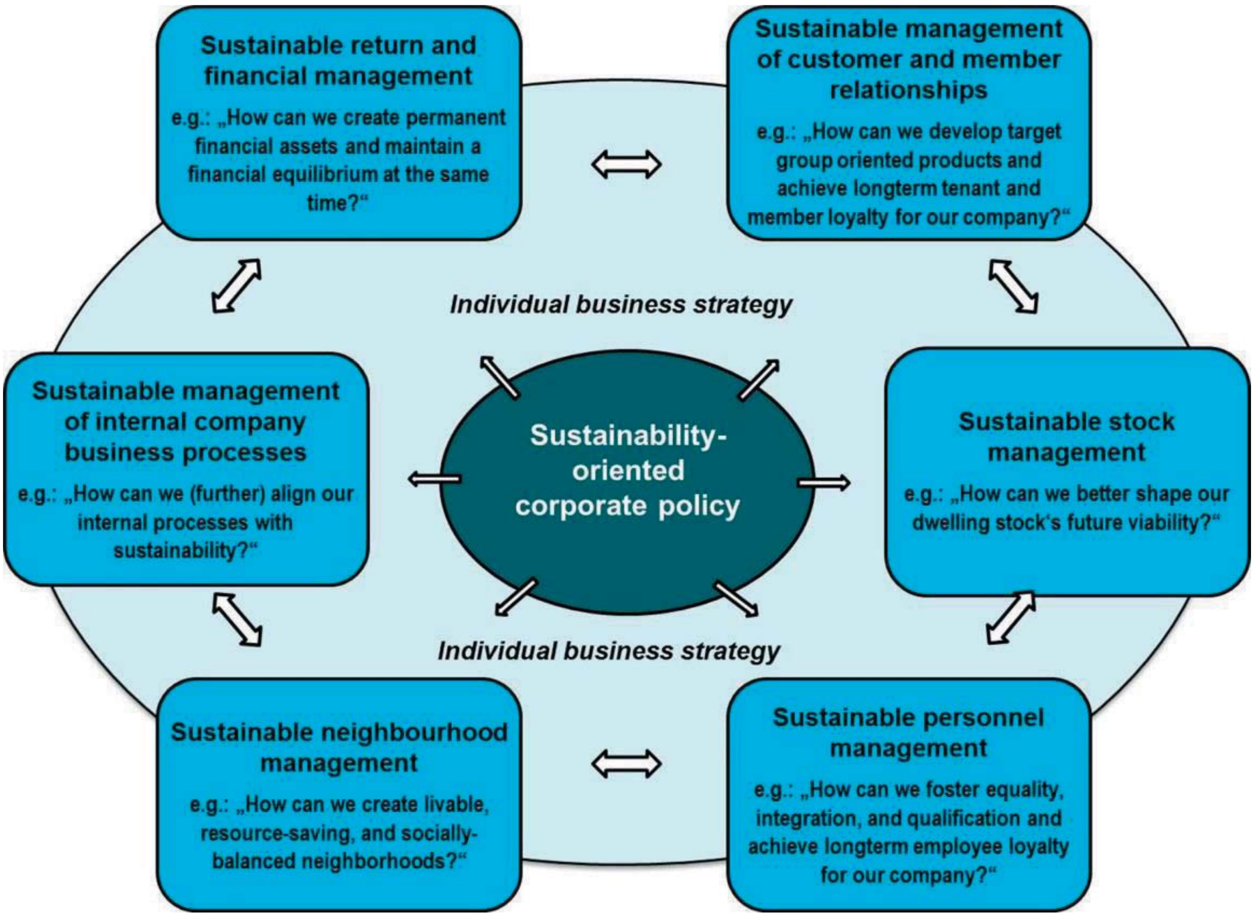

Fig. 2 System of sustainability-oriented management perspectives[8][15]

3.1 Content alignment of reporting along housing and real estate economy management perspectives

In order to increase the transparency and comparability of sustainability reports of the housing and real estate sector, both a standardisation of report content and a standardisation of the reporting structure appear to be necessary. A sustainability report of the housing and real estate economy can be considered particularly significantly if

- its content orientates itself towards societal and internal industry sustainability goals,
- its structure shows close links to typical housing and real estate economy management perspectives,
- an assignment of report topics to the information requirements of typical stakeholders of housing and real estate companies is possible.[15]

With these requirements in mind it is recommended to create housing and real estate industry sustainability reports along six typical management perspectives in housing and real estate companies (cf. Fig. 2):

- Sustainable return and financial management
- Sustainable management of customer and member relationships
- Sustainable stock management
- Sustainable management of internal company business processes
- Sustainable personnel management
- Sustainable neighbourhood management[15]

3.2 Principles of sustainability reporting

In sustainability reporting information on the effects and services of the company both in the economic and ecological and social area should be given. Therefore, in the following, "principles of proper sustainability reporting" currently discussed in literature are outlined that can serve as a decision-making aid during the process of reporting and as orientation as part of a check or review by independent appraisers.[18][19] These principles of proper sustainability reporting are based on reporting relating to commercial law affecting frameworks of proper bookkeeping[20] as well as environmental reporting affecting the principles of environmental reporting[21][22]:

- Fundamentality (significance, information relevance, suggestibility/ controllability)
- Reliability and comparability (suitability, precision, consistency, explanation of discontinuity, currentness)
- Intelligibility (clarity, clear arrangement)
- Correctness (correctness, verifiability, complete and systematic documentation)
- Balance (balanced representation of important dimensions of sustainability)
- Efficiency (careful consideration which information should be included in the report)[8]

4 Discussion and conclusions

As, in principle, there are no requirements and there is no generally binding standard for sustainability reporting, the current initiatives were compared and inspected. The housing and real estate industry pursued the goal of setting its own standards with a guide and, ultimately, with a model for sustainability reporting. When it came to the question of the best-suited instrument the declaration of conformity in the German Sustainability Code was found to be particularly viable.

It is for this reason that the *GdW Bundesverband deutscher Wohnungs- und Immobilienunternehmen* (Federal Association of German Housing and Real Estate Enterprises), building on the sustainability reporting GdW tool published in November 2013[15] together with the *RNE – Rat für Nachhaltige Entwicklung* (Council for Sustainable Development) and the *AGW Arbeitsgemeinschaft großer Wohnungsunternehmen* (Working Group of Large Housing Enterprises), developed the first industry-specific supplement to the German Sustainability Code. This expands on the DNK criteria with specific criteria that is of particular importance to the housing and real estate industry and offers an orientation aid of which activities and core points companies in the housing and real estate industry can and should report on. The industry-specific addition is not just an instrument for reporting tailored to housing and real estate companies, but also offers orientation for sustainability management.

This primarily gives the smaller and medium-sized companies of the very fragmented housing and real estate industry, which do not carry out comprehensive sustainability reporting, an instrument for very lean and focussed reporting. Companies that already publish sustainability reports according to various standards (e.g. GdW standard, GRI, EURHONET) can additionally offer a DNK declaration of conformity.

In order to be able to give the housing and real estate companies a simplified guide for meeting the DNK criteria another guide was additionally developed. For this, in a cooperative pilot project, six housing companies ran through the process of submitting a DNK declaration of conformity, made an exchange of experiences related to it as well as giving mutual advice.[23]

The German Sustainability Code is not just considered a clear addition to a sustainability report, but it also creates transparency and comparability. With the background of credibility it supports access to the markets. It draws attention to what's important and provides impulses to further process internal company sustainability management. Whilst information for reporting is gathered, an analysis of the internal structures takes place simultaneously and further possibilities of influence and potential for improvement can be shown. The employees are also made aware of the topic and can be included in the further development of the sustainability strategy. Later the declarations of compliance can also serve as a timeline, from which it can be seen how the company has developed and changed along its sustainability strategy.

The DNK builds on previously known initiatives such as the UN Global Compact, the OECD principles, the ISO 26000 and the Global Reporting Initiative, but in doing so focusses on the most important non-financial information and figures for the capital market. This was determined during a stakeholder dialogue with important stakeholders of the capital market and by various companies. The Code therefore reduces the, in part, very complex criteria, down to the essentials, whilst at the same time offering a possibility of connection to current standards.

The German Sustainability Code is also interesting considering the fact that from the 2017 business year particularly larger companies in Germany and the EU will have to make data available for environmental, social and employee interests, for observing human rights and fighting against corruption. With the submission of a DNK declaration of conformity the companies fulfil the requirements of the future EU reporting obligation for non-financial information in every aspect.[24]

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Drivers for change: Strengthening the role of valuation professionals in market transition – insights from the RenoValue research project

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Summary

A key aspect of stimulating real estate market participants‘interest in energy efficient or sustainable buildings in the wider sense is their economic benefit. Valuation professionals play an important role in this. This paper will summarises and critically reflects the results and insights gained through the RenoValue research project, a 2-year project funded by the EU Intelligent Energy Europe Programme.

RenoValue’s objective is to strengthen the role of valuation professionals in the market transition towards Nearly Zero Energy Buildings (NZEBs) and in contributing to an overall more sustainable and transparent real estate markets. Being able to demonstrate the business case to real estate market participants is prerequisite to accelerating the market transition. Valuation professionals are well placed to comment on the financial impact of both asset specific and wider market factors. Yet their ability to demonstrate the business case for energy efficiency is missing at present: most valuation professionals lack both awareness and skills to consistently take energy efficiency and wider sustainability considerations appropriately into account when issuing valuation reports and/or advising clients.

RenoValue aims to fill this knowledge and skills gap by providing dedicated training material for valuation professionals on how to factor sustainability considerations into daily valuation practice. Furthermore, RenoValue will also provide policy recommendations on how to overcome an additional key barrier that currently hinders the consideration of energy efficiency and wider sustainability considerations by the valuation community; i.e. the lack of availability of and access to robust transaction and building performance data across markets.

Keywords: property valuation, energy performance of buildings, education and training, sustainable development, data and information management

1. Introduction

1.1 RenoValue project overview

RenoValue is a 2-year project funded by the Intelligent Energy Europe Programme of the European Union. The project's objective is to develop a training toolkit for property valuation professionals on how to consider energy efficiency, the use of renewable energy and other sustainability aspects in their daily valuation practice, and consequently help them to better understand the relationship between building performance and property value so that they may advise their clients accordingly in respective valuation reports.
The 2-year project was launched in February 2014 and is led by a consortium of leading construction and real estate sector stakeholder companies and organisations and has been rolled out in 7 geographically balanced EU member states[i] at different levels of market maturity with regard to the issues mentioned above.

The RenoValue consortium consists of: RICS, the Karlsruhe Institute of Technology (KIT), CBRE, the Polytechnic of Milan, the Polish National Energy Conservation Agency, Troostwijk Real Estate, Skanska and Business Solutions Europa.
In addition, the project was supported by a high level European Valuation Steering Group[ii] including experts from investment, banking, real estate valuation as well a sector-relevant UN agency and a global green building umbrella organisation.

The project fits well into the European Strategic Energy Technology Plan (SET) which has recognised that one of the key elements for successful implementation at EU level is the availability and mobilisation of appropriately skilled human resources. In addition, the RenoValue project addresses one of the recommended actions of the SET Plan Roadmap on Education and Training: Cooperation Partnerships among Education and Training Providers, Research Institutes and Businesses. [1]

Parts of this paper draw on the RenoValue interim report published in June 2015 which presents the key findings of Phase of the project 1; see: [2].

1.2 Valuation: an essential part of the sectoral life cycle

Accurate valuations are vital for a transparent property market and a stable economy. They form the basis of portfolio performance analysis, financing and investment decisions, transactions, and land development advice as well as dispute resolution and taxation.
They also underpin the ability to demonstrate the business case to key built environment stakeholders is a prerequisite to accelerating the market transition towards Nearly Zero Energy Buildings (NZEB) in both new buildings and existing stock.

As Figure 1 illustrates, valuations play an essential role around the commercial market segment sectoral life cycle but in principle the same applies for the residential segment, however, as a rule, for owner-occupied residential dwellings there are fewer instances where a formal valuation would be required and necessary. From the perspective of using the valuation process to address key touch points that would bring about market transformation towards more energy efficient buildings, the most pivotal one is the point of transaction, e.g. when buildings are being sold or when investment decisions, such as major refurbishments are being taken.

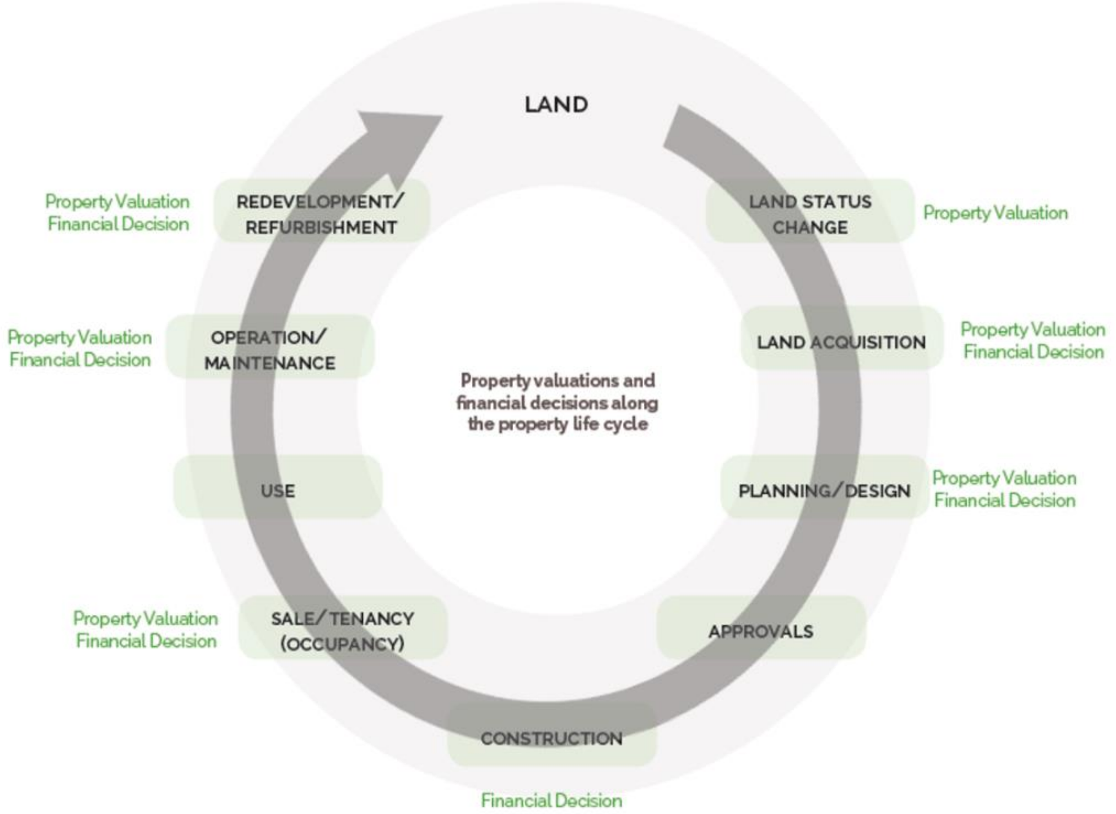

Fig. 1 Property valuations and financial decision making along the property life cycle

There is an emerging body of empirical evidence from an increasing number of markets around the world that sustainable buildings not only perform better in terms of energy efficiency but also financially, as they command higher rents or resale prices and/or they hold their value better over time. Property pricing is increasingly distinguishing between buildings that exhibit different sustainability-related building features and associated physical or operational performance (for an overview see, for example, [3] and [4]). There is recognition that buildings which are not resource efficient, low carbon in terms of operation and location and which are not equipped to flex to changing occupier needs will not be future proofed in market value terms.

1.3 Capturing the role of valuation professionals as information managers in driving market transition

There are at least 70.000 affiliated valuation professionals (and a considerable number of non-affiliated) in Europe. As part of their daily practice they comment on the financial impact of asset specific and wider market factors. While it is perfectly feasible to reflect energy efficiency, the use of renewable energy and sustainability aspects through current valuation techniques and methodologies, there is still a lack awareness amongst many valuation professionals and also a lack of dedicated training in relation to understanding valuation users' requirements and the possible value impact of existing and emerging measures and technologies targeted at improving energy performance of buildings. Understanding and translating the often rather technical resource efficiency and sustainability related building performance data is not traditionally a domain traditionally associated with valuation professionals' core skill sets. This type of knowledge usually falls more in the domain of building specialists such as architects, engineers, building controllers, building surveyors and facility managers.

Consequently, while the remit of valuation professionals is to reflect the market and not to 'make the market', the nature and scope of their advisory services clearly influence property market outcomes. This was the starting point for the conception of the RenoValue project. If Europe's valuation professionals were to offer their clients evidence-based advice and transparent qualitative judgement around energy performance issues in addition to their customary reporting services during the transaction phase, this would have a significant market impact.
Subsequently, the overarching objective of RenoValue was to develop dedicated training material that would fill knowledge and skills gaps to enable valuation professionals both to be able to meet market demand as well as to become an integral part of driving market transition towards a more sustainable and thus more energy efficient building stock in Europe as illustrated in the virtuous circle diagram in Figure 2.

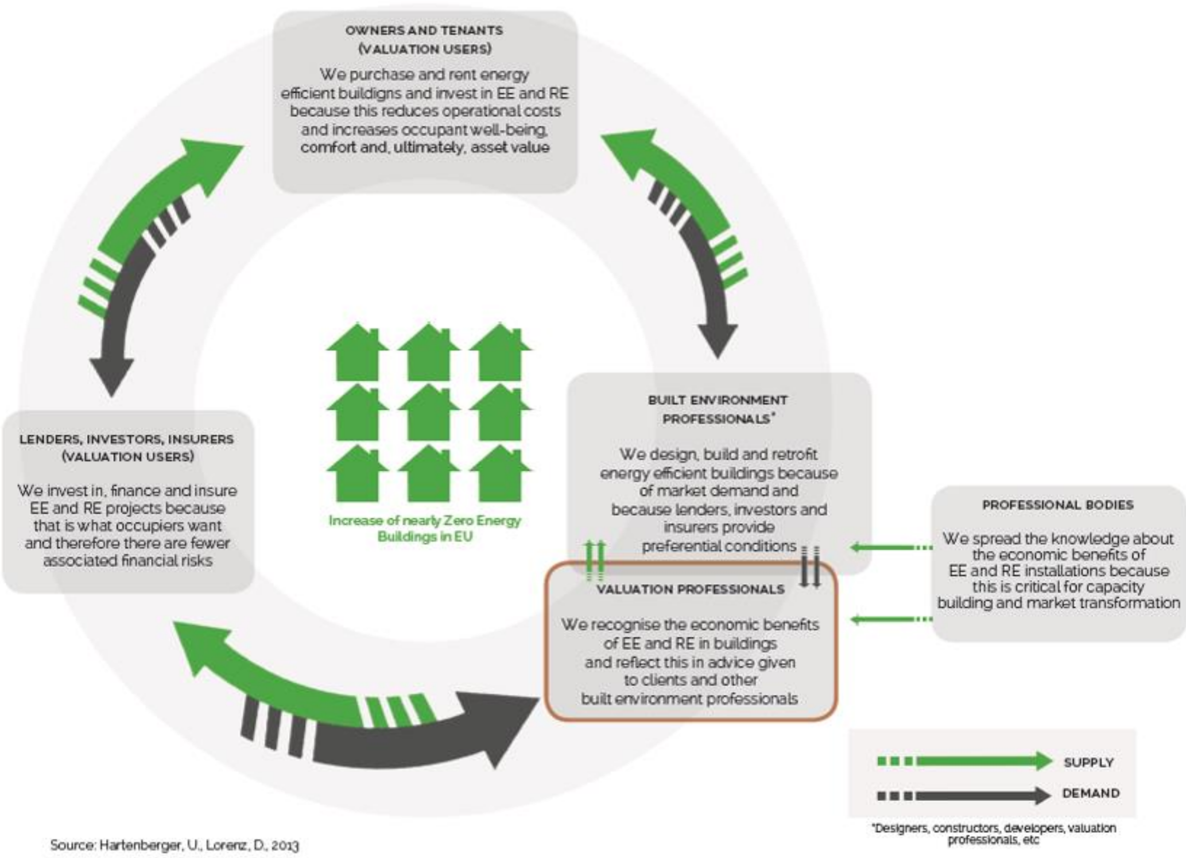

Fig. 2 A virtuous circle for NZEBs in Europe

2. Methodology

2.1 Phase 1: Valuation stakeholder survey and consultation

The key objectives of the first phase of the project were to identify valuation professionals' training needs and explore market barriers currently hindering the consideration of energy performance and other sustainability aspects.

One of the main challenges when assessing the value impact of a building's energy performance and other sustainability aspects is availability and access to robust, good quality data.

Unfortunately, in most EU member states, data evidence on financial performance and value enhancement through improved energy efficiency, the use of renewable energy or investments in other aspects of sustainability is still not readily available.
Valuable information from the design stage is often lost and building performance data are not systematically collected and managed during the operational phase. In addition, information from available data sources such as energy performance certificates is not automatically linked to transaction data and the quality of both greatly varies. Without reliable data, a valuation professional cannot factor the energy and wider sustainability performance of an asset into the valuation report. This lack of market transparency is the single most important obstacle to establishing the linkages between a building's energy performance and its value.
Therefore prior to developing the actual training material, alongside assessing valuation professionals' awareness levels, existing market barriers with regard to energy efficiency and renewable energy installations, local sentiment with regard to potential local impact on asset value on sales and rentals, the project consortium carried out a preliminary research aimed at identifying and evaluating data and information sources currently available to valuation professionals in the 7 target countries.

2.1.1 The RenoValue survey

In first instance, to help guide and prepare discussion points for the subsequent face-to-face national stakeholder round tables and ultimately inform the development of nationally adapted training material, a survey was developed with the support of the EU VSG and then electronically disseminated amongst selected valuation professionals[iii] from across the 7 member states. Table 2 provides an overview of the survey's various objectives and areas of specific interest.

Table 2: Survey objectives

Understanding the extent to which each participant was engaged in valuation activity and the type of property valuations undertaken
Identifying the primary sources of information used when carrying out valuations
Qualitatively assessing the information on property transaction data, whether held by a public or private source, and the quality of any publicly available data
Assessing the accessibility of property operational cost data and the extent of information normally provided by clients instructing valuation work
Understanding whether valuation professionals currently receive dedicated trainingregarding green labels ocertification schemes
Investigating the existence of public registers for Energy Performance Certificatesand, if any, their accessibility, and whether the consideration of other green labels or certification schemes for buildings is standard practice

2.1.2 The RenoValue national round table workshops

To be able to assess valuation professionals' training needs and valuation users' requirements regarding the integration of EE and RES features and other sustainability aspects into daily valuation practices, the RenoValue project consortium organised a series of national valuation round table workshops in the 7 EU member states taking part in the project.
To be able to get a comprehensive and representative overview of the respective market context, each round table involved approximately 20-35 participants representing the stakeholder profiles in Figure 3.

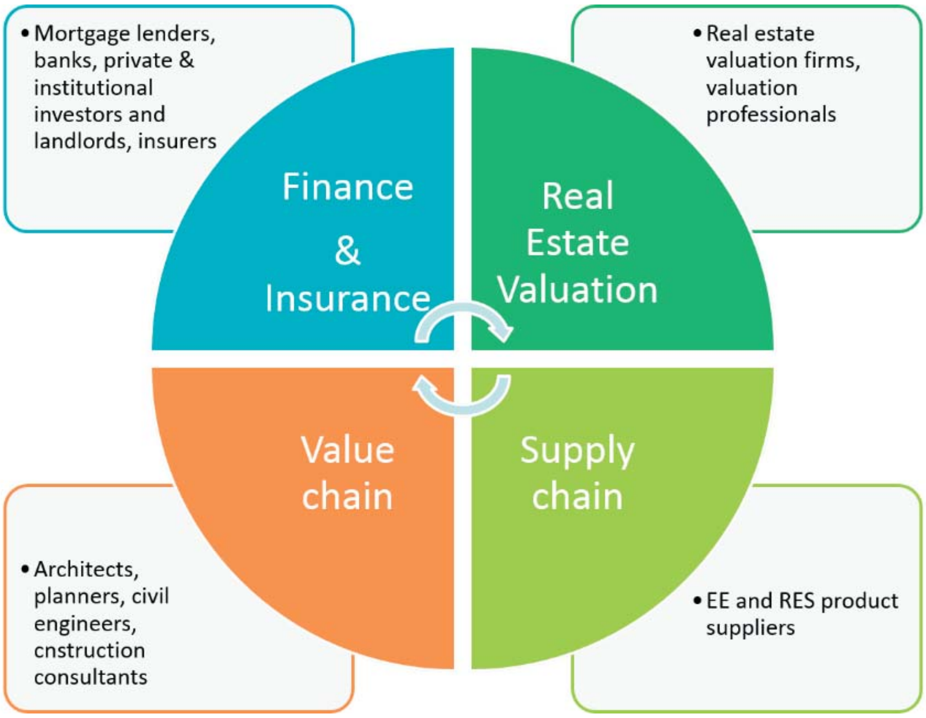

Fig. 3 Workshop participant profiles

The national round tables followed the structure of the survey themes and also served to validate the market feedback gathered from the survey phase.

3. Findings and common themes

The combination of the round table workshops and the survey responses were a crucial part of the larger project as both gave valuation professionals the opportunity to state and explain their specific needs and wish-list for the training and future valuation reports. In this way, they also helped to break down traditional communication blockages and silo-thinking along the value chain, as participants from the more technical orientated and the finance communities would not typically be in the same room to share experiences.

The findings from the round table workshops validated the overall RenoValue project objectives and confirmed the underlying assumptions at project conception stage:

1. **Current levels of awareness and knowledge with regard to energy efficiency and other sustainability aspects amongst valuation professionals across a sample of countries within Europe:**

- The level of awareness with regard to energy efficiency, the use of renewable energy and other aspects of sustainability varied from country to country, but generally it was limited. Highest awareness levels were reported for the Netherlands, the UK and Germany, the lowest being in Italy, Belgium and Poland.
- Generally, there was correlation between countries' data and information availability and awareness levels. The better the quality of information and the easier this information was accessible, the higher the awareness levels.
- Valuation professionals working for international companies displayed higher levels of awareness. One of the reasons stated for this was that these professionals are more

likely have to provide adivisory services to international clients with corporate responsibility agendas. In addition, professionals working for larger companies are also more likely to have access to the expertise of sustainable building specialists.

2. Market barriers currently hinderIng the consideration of energy performance data and other sustainability aspects by the valuation community:

- the general lack of market transparency;
- not being able to link transaction and energy performance data;
- the lack of systematic and centralised collection and management of building information; and finally,
- the lack of quality assurance procedures relating to both basic transaction data and energy performance data recorded through energy performance certificates.

3. Local market sentiment with regard to energy efficient and sustainable buildings potentially commanding higher sales or rental premiums:

- With the availability of reliable and robust local data still being the exception rather than the rule in the majority of countries examined, the empirical evidence base in relation to sales and rental premiums across those countries equally proved to be still more anecdotal and down to sentiment.
- There was general agreement around buildings longer meeting legislative requirement thresholds and client expectations risking a so-called ‘brown premium’ in the longer term, i.e. potentially incurring price discounts on buildings that no longer fullfill market expectation.

The findings from the round table workshops informed the development of the training material.

4. Development of the RenoValue training material

Regardless of national variances with regard to market maturity or level of regulatory implementation and enforcement, valuation professionals in all countries covered by the project expressed a clear need for more guidance and training on, in particular on:

- how to read, interpret and translate energy efficiency, renewable energy and other sustainability related information;
- how to consider this type of information in valuation reports for clients; and
- how to advise clients, for example highlighting potential risk and opportunities.

More specifically, participants wanted the training to address:

- awareness raising about the relevance and importance of considering energy and sustainability performance related aspects into daily valuation practice;
- fostering of technical insights and knowledge needed to verify the sustainability credentials of buildings both during building inspection and when having to assess available information sources (whether with regard to commercial or residential buildings);
- examination of the assessment criteria which inform commercial building ratings and EPCs and how an understanding of these can affect a property valuation; and finally
- how to consider the energy performance and other sustainability aspects within the actual application of different valuation methodologies.

4.1 E-learning entry level learning objectives and focus

In response to the feedback from the majority of round table workshop participants who felt that it was most important to address knowledge and skills gaps amongst mainstream valuation professionals, the project consortium decided to design training material according to the degree of of existing professional exposure. Consequently, the training package developed consisted of an entry level e-learning module in the local language at a more basic level and a stand-alone face-to-face CPD master class (Continuous Professional Development) for more experienced valuation professionals with at least five years of professional practice with existing knowledge of the subject sustainability as it relates to valuation. Both levels were based on existing RICS guidance material.
While the project foresees the e-learning as servings as an introduction to the more detailed and in-depth advanced CPD master class module, it can also be used as a stand-alone module.

4.2 Advanced module learning objective and focus

The aim of the CPD master clasess was to extend and consolidate existing knowledge and give insight and more practical focus on the results of current research and studies.
Learning objectives are focused on:

- Recognising:
    - the impact of sustainability on the wider real estate market and the valuers' critical role within the sustainable development discourse as this is not self-evident and understood by all practitioners.
- Gaining:
    - a holistic understanding of EU targets in relation to energy as this is important and will help practitioners to explain the relevance of the topic (including to their clients) sustainable buildings as well as benefits and opportunities of energy efficient / sustainable buildings
- Learning how to:
    - measure energy demand/consumption in a building
    - describe energetic quality of buildings
    - calculate the refurbishment backlog
    - evaluate the condition of a building and it's systems
    - identify the factors affecting energy performance in a building
    - identify, assess and extract relevant sources of (building-related) sustainability information
    - adopt a holistic approach for building descriptions within valuation reports
    - integrate energy efficiency/sustainability considerations in valuations
    - identify the suitability of different valuation methods and their input parameter in order to integrate energy efficiencies and sustainability considerations in valuations
- Providing:
    - An overview of current sustainability-related guidelines, guidance and requirements for valuers
    - Definitions of value and respective approaches for integrating energy efficiency / sustainability considerations in valuations

While the core focus of the RenoValue project is obviously to build capacity amongst the valuation community, as the high level of interest by other market participants during the series of round tables has shown, it is also expected that the project will also have a wider market impact.

By highlighting that an investment in a sustainable building or in energetic renovation can either increase or at least help to protect the value of their building, valuation professionals can act as multipliers, motivating building owners to engage with the issues of energy and wider sustainability performance. At the same time, through systematic collection and analysis of data valuation professionals can contribute to an overall improvement of data and information transparency.

5. Conclusion and outlook

While responses from round table participants varied due to the respective characteristics of the market they were operating in, five common themes across all seven countries emerged during Phase 1 of the research project:

1. **Lack of publicly available central databases of Energy Performance Certificates (EPCs)**
   - In most countries except the Netherlands, Sweden and the UK publicly available central databases of EPCs do not exist. Therefore valuation professionals are not able to interpret the EPC rating in relation to how energy efficiency or renewable energy could have an impact on value of a building subject to sale or purchase.
   - Even in countries where EPCs are publicly available, they are difficult and time consuming to access.
2. **Lack of internationally recognised public building rating certificates**
   - The issue of sustainable buildings appeared - albeit at varying degrees - to increasingly gain importance in all RenoValue target countries.
   - Market demand has triggered the creation of a few commercial labels that have the objective of differentiating buildings with sustainable features. However, detailed disaggregated data behind these certificates are not publicly accessible, as commercial label providers do not reveal background information but only overall certification results. Labels are therefore a limited source of information for valuation professionals. The solution would either be an addition to the label that would disclose disaggregated certification results or in the introduction of a building passport or building file.
   - There is also no publicly endorsed building certification system which is easily accessible and which could represent a reliable source of information for valuation and other property professionals.
3. **Lack of property operational cost data**
   - Publicly available information on property performance and the associated operational costs is extremely limited in any of the 7 target countries. The availability of building operational data would enable valuation professionals to assess if sustainable buildings have lower operational costs.
   - Currently valuation professionals' only source of this type of information is the client.
4. **Lack of adequate property transaction data**
   - While the availability of transaction data varied from country to country, information on individual building characteristics was either very difficult or impossible to obtain. As a consequence, the potential price differential is difficult to quantify, as valuation professionals do not always have full access to adequate comparable information.
   - In all countries it became clear that certain market players have their own internal databases of transactions. As a consequence, valuation professionals working for larger firms tend to have a competitive advantage in comparison with those working in smaller and medium-sized practices or on their own.
5. **Inadequate data quality**

- Even in the countries where information is publicly available, it is often incomplete and unreliable for valuation purposes, as the information is not always verified for quality assurance purposes.
- EPCs were generally considered an unreliable source of information.

Next steps: Once the training material has been piloted and reviewed by valuation professioals and revised on the basis of their market and professional expertise, a wide-labeled version of the training tool kit will be made freely available to all interested stakeholders for training and educational purposes.While the training material developed as part of the RenoValue project will undoubtedly support market transformation towards a more sustainable and therefore more energy efficient building stock in Europe and help to increase the number of nearly Zero Energy Buildings (NZEBs), training will need to be supplemented by a legislative framework that addresses the lack of market transparency as there are a number of barriers that are clearly beyond the control of valuation professionals. A key policy recommendation from Phase 1 to policy decision-makers would be that more efforts to enforce existing regulation need to be made to ensure that market participants have access to reliable transaction and performance data. This would ultimately help to strengthen the business case for energy efficiency, an increased uptake of renewable energy solutions and wider sustainability aspects by the built environment stakeholder value chain.

6. Acknowledgements

The authors wish to thank the RenoValue project consortium partners, the members of the EU VSG as well as all value chain stakeholders who took the survey and/or contributed to the round table discussions that helped to shape the both the interim report as well as the development of the training material.

7. References

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[4] WGBC, 2013, The Business Case for Green Building, World Green Building Council, Available at: http://www.worldgbc.org/activities/business-case/

8. Endnotes

[i] RenoValue target countries: Belgium, Germany, Italy, Netherlands, Poland, Sweden and United Kingdom; additional roll-out of training outside the original project scope: Greece

[ii] Members of the EU VSG include: Caisse des Dépôts, Cushman & Wakefield, Hermes Real Estate, European Group of Valuer's Associations (TEGoVA), United Nations Environment Programme's Sustainable Buildings and Climate Initiative (UNEPSBCI), World Green Building Council.

[iii] 87 valuation professionals participated in the survey

Ecolabelling of Building materials in Russian Federation: condition and prospects

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Summary

Comparison of requirements of the Regulation (EU) No 305/2011 (Construction Products Regulation) of the European Parliament and of the European Council with provisions of technical regulations of EuroAsEC "About safety of buildings and constructions, construction materials and products" concerning ecological requirements to products presented in the market. A situation in the market of ecolabelling of construction materials in Russia. The application of the principles of the principal-agent theory to a situation in the market of construction materials in regions of the Russian Federation. Detection of a role of information resources about ecological properties of materials in market of construction products grouping. The accounting of information construction materials at an ecological assessment of real estate objects according to requirements of GOST P 54964-2012 "A compliance assessment. Ecological requirements to real estate objects". Ways of achievement of an indicator of 30-50% of ecologically certified (marked) construction materials for a concrete real estate object.

Keywords: construction materials, environmental labeling

1. Introduction

Environmental assessment of construction materials takes special place among ways and tools of securing sustainability in construction sector. Due to this, the Regulation of the European Parliament and of the Council № 305/2011 sets a demand for «disclosure of information on efficiency» as a prerequisite of labeling construction materials intended for sale on European construction materials market [1]. Regulation of the European Parliament and of the Council № 305/2011 allows shipping foreign construction materials on EU markets upon fulfillment of several requirements.

On the Eurasian Economic Community territory a regulation «On security of buildings and structures, construction materials and products» is in draft at the moment (prepared 02.11.11). It does not suggest stand-alone consideration of construction materials security, but adds requirements to them as a separate item 10. These requirements include mostly issues of sanitation and fire security of materials through their life cycle. Problems of resources consumption, air venting on different stages of life cycle are not considered in the paper. However the EurAsEC paper actively supports different types of voluntary certification. In particular, it provides a voluntary confirmation of compliance to national and multinational standards and other papers upon which they are shipped – for materials which are not subject to compulsory certification [2].

2. Methodology

Requirements of the Russian Federation national standard GOST R 54964−2012 «Compliance assessment. Environmental requirements for property items» under the «Environmental control in property building, operation and recovery» base category stipulates that no less that 30-35% of materials and constructions used in building must have a certificate or eco-label, any of three types. As we know, there are three different types of environmental labeling: type I environmental labeling for certain products which have an advantage over counterparts due to lesser impact on environment (often as a result of using innovative solutions in production); self-declaration by the manufacturer (as a rule, characterized by the lack of special requirements for assessment subject and methods); type III environmental labeling is voluntary for manufacturers and is performed by expert organizations in accordance with certain patterns. European experts consider Type III environmental labeling the most promising one for usage in the construction area. In particular, this environmental declaration type is spreading across construction materials manufacturers in the European Union.

International practice suggests standards ISO 14025:2006 «Environmental labels and declarations. Type III environmental declarations. Principles and procedures» and ISO 21930:2007 «Sustainability in building construction. Environmental declaration of building products» as a base for environmental declarations composition. On the European level, one of the fundamental documents on environmental assessment of construction products is the EN 15804 standard « Sustainability of construction works. Core rules for the product category of construction products. Regulation». These documents include keystones of environmental declarations formulation, so we would like to make a brief analysis for each of them. Experts of CEN point out the following key aspects of the ISO 21930 standard implementation [3]:
- goal to make production declaration on the «construction phase» possible;
- life cycle description as a functional part of a composite system or the whole building;
- declaration operation issues related to the «declared production unit»;
- maintenance of modularity when declaring (databases, system level, life cycle stages).

Key matters in developing the European standard EN 15804:2012 are [4] 1. it is a part of the TK 350 standard system; 2. it includes the basic rules for using in all national declaration patterns; 3. it fixates the declarations composition methodology; 4. it can be used for declarations composition beyond the building life cycle assessment process and does not depend on declaration pattern being used; 5. it includes references to the European quality standard, EN 15978; 6. it provides a possibility of developing social and economic assessment standards.

Experts from Sweden note the difference in analysis scope between the above mentioned documents ISO 21930 and EN 15804. In particular, the international standard ISO 21930 involves development of environmental declarations focused mostly on production stage. Selection of a declared unit is focused on it as well. In case of the European standard declaration might involve construction materials installation, maintenance and recycling. Such consideration of life cycle stages can be performed both individually for each stage and for all stages together. The latter option requires utilization of certain rules for different product categories (*Product Category Rules*) [5]. At present there are two fundamental directions of life cycle assessment development: 1) the need to stipulate requirements for each construction product category and further declaration of its impact on environment; 2) the integration of data on construction materials and other products into buildings assessment system.

Speaking of the Russian Federation we suggest to consider and compare declarations' requirements against criteria introduced by the GOST R 54964−2012 «Compliance assessment. Environmental requirements for property items». The «minimization of materials used in construction impact on environment» gauge belongs, according to the standard, to the «Environmental control in property building, operation and recovery» category. Assessment on the given gauge includes the following indicators: share of environmentally certified construction materials and structures being used in construction; utilization of local construction materials; utilization of recyclable materials and production of vegetable origin; utilization of finish materials, paints, coatings based on natural materials; utilization of thermal covering based on natural materials (basalt, sand, wood); prohibition on utilization of materials of wood species listed in the Red Book of the Russian Federation in building construction and decoration. Analyzing the proposed indicators we must note that essentials are the first two of them, regarding the utilization of environmentally certified local materials. With that, it would be optimal to mean by environmental certification the type III labeling, i.e. declarations on construction materials environmental impact. By the way, in this case the rest of GOST R 54964−2012 indicators lose their value because declarations already provide us with necessary information. The standard refers to the GOST R 14031−2001 «Environmental control. Environmental efficiency assessment. General requirements» as minimal requirements to share of environmentally certified materials, though in the long view it is required to refer to the ISO 14025:2006 and ISO 21930:2007 standards. Some of the indicators (for instance, prohibition on utilization of rare wood species) have nothing to do with the buildings and structures assessment process. Thus, we can conclude the necessity of environmental requirements for property items further development towards construction materials assessment criteria. It will take a system approach to regulatory framework development, beginning with documents harmonization process on international level.

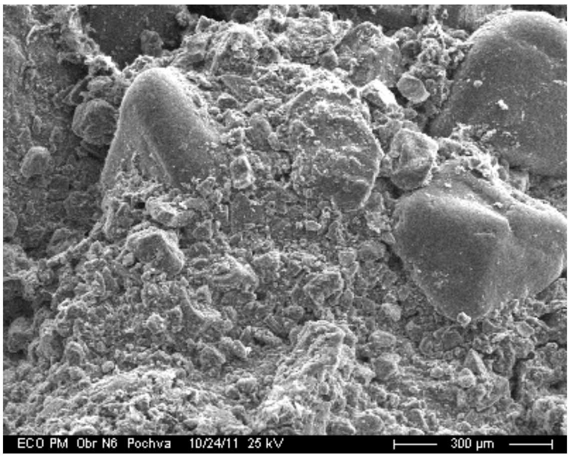
3 Results

Now we will try to consider the main challenges and opportunities of environmental declarations spreading in Russia.

1. In the context of the Russian Federation membership in the World Trade Organization as well as trade-economic integration in the form of the Eurasian Economic Community customs union a tool for declaration of impact on the environment through life cycle of construction materials allows harmonizing environmental requirements and making them available for all participants of design and construction process.
2. It is important to understand the competence regarding information on hazardous emissions of construction materials. In particular, the Federal Supervision Agency for Customer Protection and Human Welfare controls emissions of construction materials presented on the market. Environmental control authorities perform monitoring in production manufacturing areas. Declarations include information on all life cycle of construction materials. With that, methods of calculating toxic elements emissions through life cycle must be developed (taking into account methods used by the above mentioned authorities).
3. Technical regulation provides an opportunity of voluntary environmental certification and development of Type III declarations. However, further work on evidential base of sustainable construction in terms of developing directions of environmental impact declarations for Russian enterprises and including information on construction materials into property items environmental assessment systems.
4. As long as large manufacturers associations play significant role in development of product category rules, it is possible that in Russia this job can too be performed by self-regulated organizations of construction materials manufacturers. Activity centralization pattern as in the German Institut für Bauen und Umwelt is also possible.

5. Due to the difference in technologies being used by domestic construction materials manufacturers as well as absence of national organization for coordination of declarations composition one can encounter difficulties in creating databases on fundamental construction materials. Such bases have already been composed in a range of countries to help architects, designers and other participants of construction.
6. It is necessary to develop and enhance tools and methods of life cycle assessment which will be used in order to compose declarations on construction materials environmental impact. While developing, industry and national aspects should be considered.
7. Many manufacturers are disadvantaged by composition of environmental impact declarations due to utilization of outdated technologies and considerable power consumption of manufacturing process.

Environmental issues of construction materials production in Russia must be reviewed from two essential points: 1) maintaining production safety regarding its toxic impact on human and environment through its whole life cycle; 2) consideration of product power consumption factor and global environmental impact through life cycle stages.
As for construction materials safety considering utilization of toxic components, it is necessary to perform investigations of soil on one of the enterprises using phenol-formaldehyde resins as binding agent. Pictures of soil fabric show almost total absence of microorganisms, which implies excess concentration of formaldehyde (Fig. 1). It creates additional difficulties when ecolabelling construction materials at the Russian enterprises.



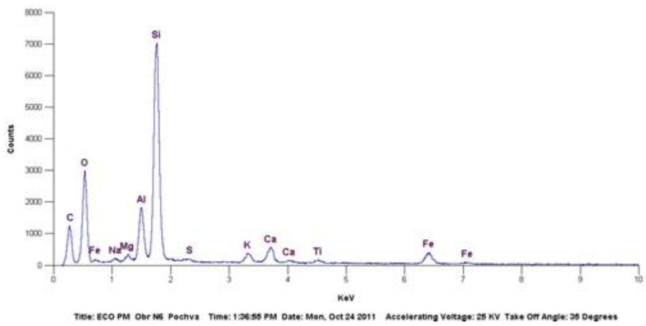


Fig. 1 Microscopic picture and the X-ray diffraction analysis of a sample of the soil from the enterprise of fibrous heat-insulating materials (at finished goods warehouse)

When considering power consumption issues through product life cycle and global environmental impacts we should perform a comparison between Russian and European manufacturers.
Table 1: Analysis of fibroid thermal covering products fabrication environmental impacts in terms of equivalent units

Material name	Greenhouse effect formation potential, kg CO_2-equ./ m^3	Acidification potential, kg SO_2-equ./ m^3	Ozone destruction potential, kg CFC-equ.	Excessive fertilization potential, kg PO_4-equ.	Photochemical smog formation potential, kg ethylene-equ.

Rock wool, produced in Germany	1,37	$8 \cdot 10^{-3}$	$1,3 \cdot 10^{-7}$	$8,9 \cdot 10^{-4}$	$8,9 \cdot 10^{-4}$
Glass wool, produced in Germany	2,09	$15,3 \cdot 10^{-3}$	$1,1 \cdot 10^{-7}$	$9,2 \cdot 10^{-4}$	$9,1 \cdot 10^{-4}$
Rock wool, averaged data on manufacturers in European Russia	2,21	$9,8 \cdot 10^{-3}$	$1,7 \cdot 10^{-7}$	$9,7 \cdot 10^{-4}$	$9,3 \cdot 10^{-4}$

Obtained results show that Russian manufacturers are slightly behind European suppliers of rock and glass wool. In this regard we propose a method of construction materials environmental efficiency assessment.

Implementation of environmental declarations in Russia is advancing slowly due to the lack of manufacturing companies' interest. The relationship between the actors in the direction of market development markings are shown in Figure 2.

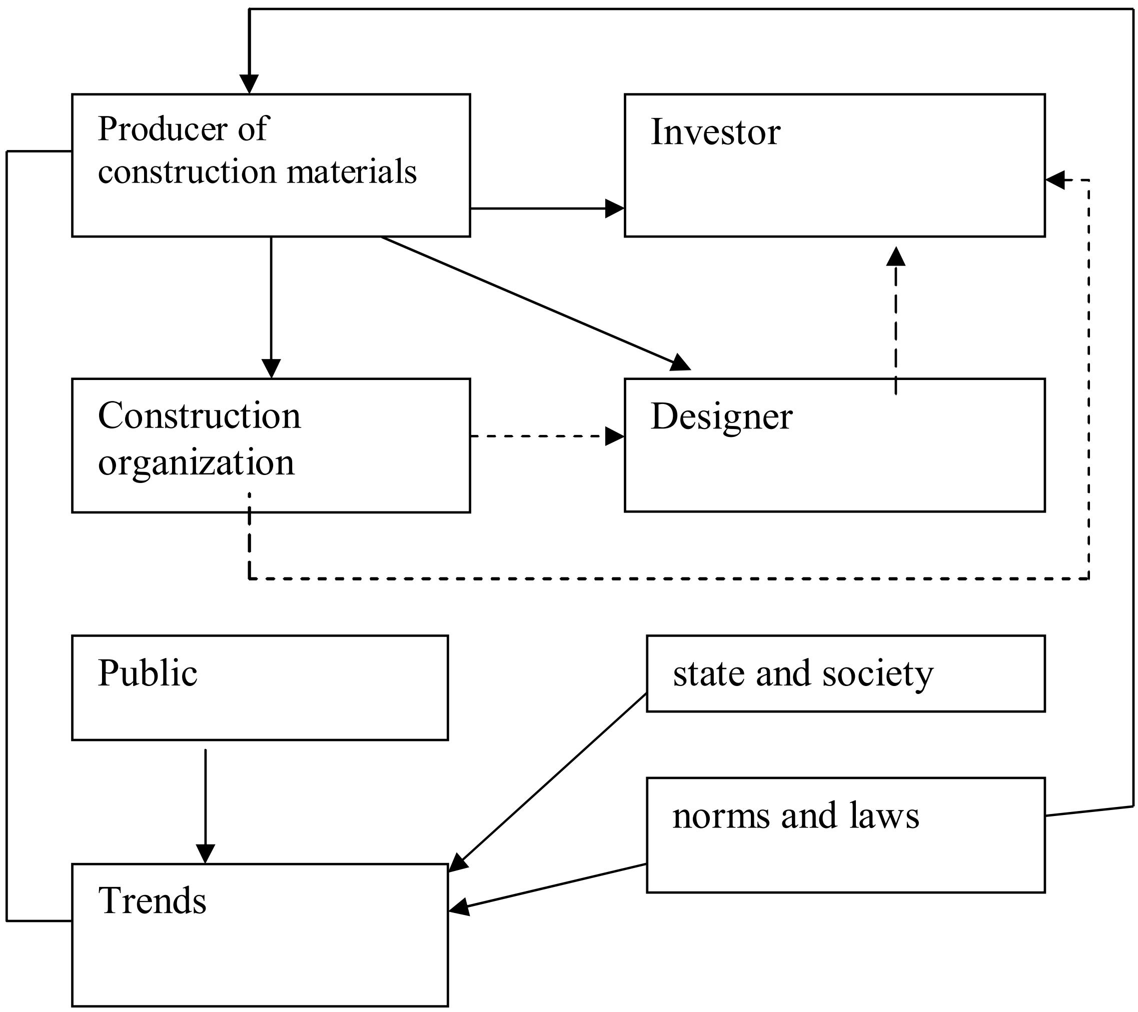


Fig. 2 The relationship between the actors in the direction of market development markings

At the same time, it is necessary to take steps towards establishing it. Possible measures on the part of authorities:

1. Include sections describing sustainable construction subject, in particular related to construction materials choosing with account of environmental requirements. Additionally it makes sense to define special requirements for construction materials industry in regard to compliance with environmental and social standards, composition and publication of environmental declarations, etc., as well as for commercial enterprises (customers' information procurement issue).
2. Development of regional-specific programs for environmental proof construction materials market stimulation.
3. Funding research and development (for example, databases with information on materials environmental impacts).
4. Development and finance of consultation programs for private developers.
5. Implementation of the compulsory documentation list for construction products being used.

Proposed measures on the part of industry:

1. Enterprise design with account of sustainability requirements (location, environmental impact assessment, proximity of mineral deposits and raw materials, selection of utilities, selection of technologies, etc.).
2. Permanent processes optimization, improvement of product quality and product development with account of environmental requirements.
3. Implementation of sustainability assessment systems for production and manufacture with the goal of minimizing environmental impacts.
4. Development of manufactures with support of regional authorities and professional community.
5. Agreement on full responsibility for product quality.
6. Further development of environmental situation account structure on the factory.
7. Improvement of information on product, including development of environmental declarations.
8. Further development of consultations on product optimal utilization and accurate processing during installation on construction site within requirements for health protection and environment control.
9. Commitments for production processing and recycling upon their life cycle completion.

4 Discussion

Construction materials environmental security assessment method must include raw materials accessibility. Manufacture location must be assessed from a city planning point of view as well. While assessing the enterprise itself one should take into account criteria put in buildings environmental certification systems and sustainable construction evaluations. However compliance with the requirements of ISO series 14000 standards on environment quality system is important for production as well. Furthermore, experience shows that any system must be adapted under certain industry and region specification. Logistical issues are included in assessment as well. Installation quality, thermal covering materials maintenance accuracy and duration as well as possibility and ease of assessed materials recycling process are important. When assessing the maintenance stage it is necessary to take into account enclosing structures construction solution options.

It is possible to develop a single national tool for fibroid thermal covering materials assessment, which will reflect many aspects of their life cycle. In developing this tool both computational and expert assessment methods must be used. In particular, methods from the theory of risk (Elmeri method, Fine & Kinney method, etc.) can be used as a methodical base, qualimetry methods (for example, drawing the Shewhart diagram) play significant role. Furthermore, there are methods of generating characteristic mesh, environmental screening, environmental footprint, environmental impact calculation, and so on, which have already proven themselves good for construction materials assessment. One of the most important indicators of power source efficiency is an «energy return on investment» (*EROI*) [6] index proposed by Charles A.S. Hall, College of Environmental Science and Forestry, the State University of New York (Syracuse, USA). The higher this indicator for power sources is, the more return will be with the same investment. Disadvantages of a method of comparison with the help of coefficient are effects from carbon dioxide emissions, and also a factor of inconstancy of alternative energy sources. Among disadvantages of comparison method with the use of this indicator mention carbon dioxide emissions and alternative energy sources instability factor. Such indicator is suggested to describe materials which allow saving significant amounts of power due to their operation in enclosing structures. In this case the indicator is as follows: specific amount of the power saved, reduced to material cubic meter is divided by amount of the power invested through all life cycle of the material, also reduced to cubic meter. When calculating the first indicator one should consider in what form and for what construction type is the thermal covering material used as well as climatic variables of the reviewed year.

5 Conclusion

It is possible to draw a conclusion on need of improvement of ecological requirements to real estate objects concerning criteria of an assessment of the applied construction materials. System approach to development of regulatory legal base, since processes of harmonization of documents at the international level is for this purpose necessary.

We considered the main problems and prospects of a wide dissemination of ecological declarations in Russia. Environmental issues of construction materials production in Russia must be reviewed from two essential points: 1) maintaining production safety regarding its toxic impact on human and environment through its whole life cycle; 2) consideration of product power consumption factor and global environmental impact through life cycle stages.

Despite that introduction of ecological declarations of production slowly moves ahead in Russia due to the lack of interest in them from production companies, it is necessary to take steps for adjustment of such work. We considered possible measures on the bodies of state regulation.

Implementation and wide distribution of environmental impact declarations must become a factor of stimulating Russian construction materials manufacturing enterprises towards production modernization and improvement of ecological situation in enterprises location. Moreover, with the distribution of declarations improvement of materials environmental characteristics and easement of work with construction products for all participants of design and construction process must occur. One of the possible ways of implementing environmental declarations for construction products may be a way of developing national standards on construction materials environmental assessment.

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Effects of a building-integrated photovoltaic system on a high-rise estate in Hamburg, Germany

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Summary

This study focuses on the effects of the implementation of a PV system on a forty-year-old high-rise estate, which is located in one of Hamburg`s disreputable districts. To look at these effects in a holistic way, economic, ecological, as well as social impacts, were researched. The analysis has revealed that 45% of the settlement's electricity demand can be covered with the suggested PV system. Furthermore, the investment can be amortised within a reconcilable time span creating a win-win situation between the owner and the tenants. Moreover, such an installation would lead to an avoidance of about 131 tons of CO_2-equivalents per year. The valorized visual appearance of the building could reduce vandalism, increase the energy awareness and lead to proudness among the inhabitants, enhancing the neighborhood's character and its reputation within the rest of the city.

Keywords: roof-integrated PV system // façade-integrated PV system // social impacts of PV systems // holistic approach of on-site electricity production

1. Introduction

As the statistics show, Germany is striving to reach the goals of sustainable development and is one of the countries, that is successfully following the Kyoto protocol and is annually decreasing its greenhouse gas emissions. Thanks to actions taken in areas such building modernisation, transport and energy, the country has already achieved a reduction of more than 20% on 1990 CO_2 emission levels. Furthermore, the government has set greenhouse gas reduction targets, which aim at a reduction of GHG emissions of 40% by 2020 (compared to 1990 levels) [1].

The GHG emissions come from a variety of different sources. As of 2012, the majority of the sources where divided as it follows: energy industry (377 $MtCo_2$; 40,1%), industry (185 $MtCo_2$; 19,7%), transport (151 $MtCo_2$; 16,1%), households (94 $MtCo_2$; 10%), agriculture (76 $MtCo_2$; 8,1%), commerce and services (42 $MtCo_2$; 4,5%), for a total of 940 Mio Tonnes Co_2 [1].

Fig. 1: Analysed sector of Kirchdorf Sued (blue), possible PV system integration // own graphic.

While the energy transition is making its course, Germany, as well as many other countries, is confronted with issues related to obsolete infrastructures, aged building stocks as well as inefficient transport systems. If they are not renewed in the near future, they will hinder the country`s progress toward sustainable development.

Solar energy and PV systems are just a partial answer to the manifold questions concerning sustainable development - and should always be seen as a part of a bigger picture in the conception of a project development. We decided to do the research that follows, to understand the possible effects of an on-site power production by implementing PV systems on the flat roof as well as on the façades of a high-rise estate of Kirchdorf Sued, located in Hamburg (Germany).

There is a myriad of papers confirming the benefits and pitfalls of such systems, but normally the knowledge gained is limited to the technology itself or to its environmental and (socio-) economic effects. In this paper, by adding a possible social value of a PV system, we aim to widen the field of opportunities that are within the realms of possibility.

What we would like to achieve with this paper is 1) to examine to what extent it is possible to cover the analysed estate`s electricity demand, 2) to point out, which installation type would be the most suitable, 3) to understand the monetary as well as non-monetary benefits that arise for the different stakeholders and, 4) to determine the effects, if such a strategy would be amplified on a bigger scale.

The paper is organized as it follows: 1) the methodology used for finding data and calculations is explained, 2) a brief historical background of the context is given as well as the key data and the calculation of the assumed energy consumption, 3) the results of two PV systems options are explained as well as the results on the fulfillment of demand, 4) the economic, ecological and social effects of such an intervention are explored, and, 5) a reflection is made.

2. Methodology

Calculations refer to only one representative part of the settlement (Fig. 1). Calculations of the areas and volumes were done using official drawings of the city of Hamburg [2]. All the data related to inhabitants, population density and household size are taken from the statistics done by the "Statistisches Amt für Hamburg und Schleswig-Holstein" and refer to the year 2012 [3][4]. The energy demand and the annual expenses for heating and DHW were computed using the data found on Tabula tool [5]. The electricity consumption per household is an assumption made by computing the electricity demand for a three persons household (3'500 kWh/a, [6][7]) and applying it to Kirchdorf Sued (average household size = 2.58 persons, [4]). For calculating the annual expenses of the electric energy consumption, the average consumer price of 0.285 Euro was adopted [7]. As a basis for calculating the electricity harvesting potential, the online software PV*SOL was use [8]. Please note: In this paper only the results of the calculations will be shown; all the calculations are part of a more detailed report and can be requested to the authors.

3. Kirchdorf Sued`s inventory analysis

The analysed high-rise complex is called Kirchdorf Sued and is located on the island of Wilhelmsburg, approximately 12km away from Hamburg‘s inner-city [9]. Due to its location, Wilhelmsburg has developed from a rural community into an industrial and residential district with a conglomerate of various housing typologies and manifold land uses. In 1962, a disastrous flood event hit the island, resulting in a rapidly declining social and economic situation [10]. Nonetheless, between 1974 and 1976, the housing complex of Kirchdorf Sued has been constructed in island`s south [9]. In 2012, 6‘238 inhabitants lived in the settlement - this corresponds to 17‘224 inhabitants per square kilometre [24]. Kirchdorf Süd belongs to Wilhelmsburg‘s disadvantaged neighborhoods, with a high unemployment rate, low-income levels, a high ratio of social security benefits recipients and an above-average proportion of foreigners [10]. In the recent decades, many social and cultural institutions have been implemented, and a refurbishment of the buildings has taken place from 1992 until 2003. Although the neighborhood has strongly benefited from these interventions and the quality of life could be enhanced significantly, its image in the rest of Hamburg is still beleaguered [11][12].

The considered part of the settlement has a footprint of 1‘900 m^2, is eight floors high and has a number of 210 households with a total of 542 inhabitants. The settlement, that belongs amongst others to the „Vereinigte Hamburger Wohnungsbaugenossenschaft“ and to SAGA GWG, is built in pre-fabricated concrete and was retrofitted in the 1990ies, when supposedly, the facades, the windows, and the heating systems have been updated [12].

With this kind of setup, the energy demand has been calculated with Tabula Tool. The results reveal that the heating energy demand amounts 691‘220 kWh/a, the delivered energy is 1‘124‘040 kWh/a, and the total primary energy requirement for heating is 1‘626‘628 kWh/a. It is possible to observe that the losses between the delivered energy and the demanded energy are high (almost the 40%). We assume that this is due to the aged building envelope. With a newly refurbished envelope it would be possible to cut these losses considerably. The electricity demand was calculated assuming that one household composed by the average of 2.58 persons has a yearly demand of 3‘010 kWh. In total, the yearly electricity consumption amounts to 632‘100 kWh/a.

4. Installation configuration of PV systems

Thinking about the building envelope`s extensive surfaces, the idea to install solar modules suggests itself. However, the reality is slightly different. As it is possible to see in Fig. 1, most of the façades are irregularly built. There are setbacks that are often in shadow, there are balconies as well as other jutting volumes that create shadow and there is a dense windows raster that makes the installation of PV modules on the façades almost unreasonable. The roof, even if it is a flat one, has at least two different height levels that, similarly as it happens with the balconies, do not permit a regular sun irradiation. As a consequence, the performance of the modules, which are connected in series, is negatively affected.

To tackle these problems, as it is also shown on Fig. 1, the following are the measures that could be adopted for the calculation of the possible energy harvesting:

- The PV modules will only be installed on façades that are even and windowless.
- The PV modules will be installed on all the balcony parapets that are not shadowed by nearby jutting volumes.
- The PV modules on the roof will be installed at a continuous height (corresponding to the maximum building height) and will either be placed on top of existing volumes or on light sustaining structures. Like this, mutual shadowing will be prevented.

The results of the calculations show that the possible energy harvest from the façades, using only the ones that are suitable for a high-efficiency rate (southwest and southeast), results in a PV power of 105.79 kWp, and a possible grid feed-in of 57'370 kWh/a. According to the Fraunhofer Institute [13], the cost of 1m^2 fully installed - meaning including all necessary components - PV system varies between 1'000 and 1'700 Euro. Hence, the costs for the system`s installation would be in the range of 105'791 to 179'844 Euro.

The possible energy harvest from the roof - flat arrangement roof (called “option A”) or with a tilt angle of 30° (called “option B”) - could reach a PV power between 86.63 and 178.50 kWp. The anticipated costs lie in between of 86'632 and 303'450 Euro.

The total energy harvest, if the different areas (facades and roof) are summed up, could have a PV power of 284.29 kWp with a yearly electricity production of 197'740 kWh (option A) or a PV power of 192.42 kWp with a yearly electricity production of 128'561 kWh (option B). The costs of option A would range between 285'291 and 483'295 Euro. Due to the smaller amount of PV modules used on the roof, the costs for options B vary between 128'560 and 327'119 Euro.

Having a look at the yearly electricity demand of the whole building (632'100 kWh), with option A it would be possible to cover 45% of it, whereas with the option B it would be 31%.

5. Impacts of a PV system in Kirchdorf Sued

Even though, as described before, it is not possible to completely cover the electricity demand of the settlement, the utilisation of the produced power has to be considered. Depending on the further usage, the impacts of such an installation vary to a certain extent. In order to look at these effects in a holistic way, monetary, as well as non-monetary impacts, have to be examined. In this section, the economic, the ecological as well as the social aspects are investigated.

5.1 Economic aspects

As we have seen in the previous chapter, there are at least two different configurations that could be applied for harvesting PV-generated power in the analysed building. The question of choosing the one or the other solution is related to the financial power of the photovoltaic power plant's owner. For simplifying the process of calculating the possible monetary revenues, we decided to use option A as a basis for the calculations (higher investment, bigger energy harvesting) using the average price for the installation costs of 1'350 €/m^2. What follows are possible scenarios, in which the harvested energy could be used to generate a monetary income.

5.1.1 Scenario 1 | energy is used off-site, feed-in tariff as revenues

Electricity created by photovoltaic power plants is still not competitive with the ones produced from fossil fuels or nuclear power plants. To make PV power plants competitive, a so-called "feed-in tariff" for renewables has been stipulated in the German Renewables Energy Act [23] to offer investors a reasonable payback period. Depending on the PV plant`s date of commissioning, the feed-in tariff is given by the state for every produced kWh during a timespan of 20 years [6]. In November 2014, a plant with a power of between 40 kWp and 500 kWp receives 10.90 €cts per kilowatt-hour produced [23]. Looking at "option A", the yearly production of 197'740 kWh would account revenues for approximately 21'554 €/a. With a blocked tariff for 20 years, that would lead to a total revenue of 432'072 €. Thinking about the average installation costs calculated earlier (383'793 €), it is possible to assume that the system will be amortised in about 18 years and within 20 years it will result in a profit of 48'279 €. But what will happen when the feed-in tariff is expired? After the phasing-out of the feed-in compensation, the PV system does not have to be dismantled. The produced power can from then on be resold to the then actual electricity market price. This scenario is based on the assumption, that the owner of the building - for example the SAGA GWG - is also the holder of the PV power plant.

5.1.2 Scenario 2 | energy used on-site, directly sold to the building's tenants

As already seen before, with a PV system installed on the roof and the facades, it would be possible to produce enough energy to cover 45% of the household's electricity demand. Due to the fact, that no storage batteries are included at the moment, the PV-generated electricity has to be used immediately. As described in scenario 1, the power could be fed into the normal grid. However, the second scenario starts from the premise, that the owner of the PV system acts as an electricity supplier and sells the generated power to the tenants. In this case, the electricity is directly used on-site.

There are two possible ways to sell the power. The first option is that the owner sells the tenants only the PV-generated power. Hence, the tenants keep an additional power supply agreement with a local electricity distributor. This is necessary because in any case only 45% of the total demand can be covered. The second option is that the owner of the PV system becomes a full-fledged electric company. For this purpose, the necessary residual current is bought by the owner from a local electricity provider and is then offered together with the PV-generated power the tenants as a full package. This might be more convenient for the tenants because they have only one contract and therefore only one bill to pay [14].

Although in both cases various the maintenance as well as taxes, such as the EEG reallocation charge and the value added tax, have to be brought to account, this scenario seems to be more profitable to the owner of the PV system. Due to the fact, that the neighborhood of Kirchdorf Sued is facing some challenges, it might be advisable to deposit a certain percentage of the revenue in a fund that can be used for investments related to the community's benefit.

5.1.3 Additional possibilities

There are additional ways on how to use the PV-generated power than the aforementioned scenarios. Further investigations could be done in order to find out synergies to related issues, such as e-mobility or power to gas (P2G) technologies.

5.2 Ecological aspects

In Germany the feed-in of electricity, which is generated from photovoltaic systems, has legal priority in the energy grid. Hence, it is placed at the beginning of the pricing scale based on the merit order effect and is, therefore, always sold as soon as it is available. The highest amount of PV power is produced during the day, when the power consumption reaches its noonday peak [6]. During these time frames, the PV power predominantly supersedes electricity generated from cost-intensive power plants, such as pumped storage or gas-fired power plants. As a result of this displacement, the overall price for electricity - and consequently the profits made by the providers generating power from nuclear sources and fossil fuels - is lowered. Furthermore, it diminishes the degree of utilisation and, therefore, the profitability of conventional peak-load power plants [6]. Considering the fact, that in 2012 already 4.6% of the gross electricity production was generated by PV systems (renewable sources: 21.6%), the consequences for conventional providers should not be underestimated [7]. It is a fact that photovoltaic installations are increasingly clashing with nuclear and old lignite power plants with slow start-up and shutdown processes. Nevertheless, these power plants are currently almost covering the entire base load [6].

Although PV systems will not be able to replace nuclear and fossil fuel power plants in the near future, they are capable of reducing the consumption of imported energy, the use of fossil fuels and consequently the CO_2 emissions. Studies have shown that in 2013, each kWh of PV-generated power saved approximately 2.2 kWh of primary energy [6]. By adapting these numbers onto the proposed PV installation in Kirchdorf Sued, this would result in approximately 435 MWh of saved primary energy.

By 2020, Germany aims to reduce its CO_2 emission by 40% compared to 1990 levels [1]. The emission factor [gCO_2-equivalents/kWh] of PV-generated power is significantly lower than the ones of fossil fuels [15]. Studies have shown that the level of avoided emissions by installing PV systems is 664g CO_2-equivalents per produced kWh [6]. Looking at the proposed PV installation in Kirchdorf Sued, this would lead to an avoidance of about 131 tons of CO_2-equivalents per year, which is comparable to the emissions generated by 46 tons of coal if burned for generating electricity [16].

5.3 Social aspects

During our research we wanted to to find out, why the neighborhood is provoking predominantly negative associations and if the installation of a PV system could have the potential of giving a positive impact on the aura related to the neighborhood. Therefore, we have extended our research to expert consultations as well as field visits and conducted interviews with various inhabitants.

The up to 14-storeyed high-rise buildings create an oppressing, comfortless atmosphere and negatively influence the settlement`s outer appearance. Moreover, the dwelling`s homogenous building fabric and predominantly consistent - rather outdated - design vocabulary intensify this ambiance. The buildings' silhouettes, as well as their shapes, convey a feeling of Le Corbusier's Unité d'Habitation - an efficiently built high-density housing complex. While Le Corbusier suggested mixed usages in the so-called "vertical city", Kirchdorf Sued's multi-storey buildings are nearly exclusively intended for residential purposes [17]. This one-sided utilisation is reflected and clrearly readable in the monotonous building typology. As a consequence, the settlement's visual richness is severely low and is strongly lacking from pleasantness.

According to Stefan Forster, an architect from Frankfurt, residents do unconsciously perceive the architecture's poorness. Hence, they tend to treat their surroundings quite carelessly. Furthermore he states, that reiterative, rather anonymous architecture leaves an unattractive, uninviting atmosphere and does not foster cherished togetherness [18]. In Kirchdorf Sued, this statement can be approved - traces of vandalism and regardlessly discarded waste can frequently be seen. Although we cannot prove to what extend these occurrences are a result of the buildings' characteristics, we can certainly assume, that an architectural intervention could result in an enhancement of the visual appearance.

5.3.1 Reduced vandalism and enhanced visual appearance

In general, vandalism is induced by “malicious greed, by the wish to draw attention to a particular condition, by a political ideology, by the desire for revenge on a particular person, by frustration, or by misguided playfulness” [19]. At the moment, traces of vandalism can be spotted here and there. Not only the buildings and street furniture are damaged from vandalism, but also the settlements atmosphere is suffering from it. As a consequence, to some extent the settlement is radiating some kind of unkemptness and dilapidation.

The reasons, why Kirchdorf Sued is suffering from intentional damage, may be manifold and have to be tackled multilaterally. However, in order to prevent vandalism, the building’s visual appearance is an important factor. A valuable object is less endangered of vandalism because it residents appreciate it to a higher extent [18]. In order to change the rather unpleasant atmosphere, the building heights, building shapes or the design of the building envelopes could be modified. Since it is not possible to adjust the high-rises’ tallness to a more human scale nor to significantly reshape the buildings, a change in the building fabric might have a positive effect on the settlements character.

As a partial solution of the redesign and as already suggested in prior chapters, PV systems could be installed on the roof as well as on the façade and balconies: that would leave an eye-catching impression - the distinct change of colour and the slightly shiny surface finish of the solar modules would drastically change the visual appearance of the buildings. Not only the cladding’s colour and surface character would be diversified, but also its perceived value. According to Forster, this effluent increase in value has an impact on the residents, and they would endow it with higher appreciation. As a consequence, the residential environment could be perceived as more pleasant, and the resident’s contentment could increase [18].

By upgrading the settlement's visual appearance with the aid of added PV systems, the rioters' inhibition thresholds to wilfully damage something, can be considerably increased. This effect can even be reinforced by actively including inhabitants in the planning process, implementation as well as the upkeep of the PV systems. This participatory process triggers a feeling of responsibility and can prevent prospective vandalism [18][20].

5.3.2 Increased awareness leads to proudness

According to Everett M. Roger`s book "Diffusion of Innovation" [21], the adaptation of innovation is determined by various attributes - incentives, status aspects, economic factors and relative advantages. Although the residents do not have to invest by themselves in the installation of the PV system, it is important that they prevailingly agree to its implementation. If they consider the PV panels as unnecessary, alien-looking gizmo, the acceptance and the awareness of benefits are low.

There are two possible approaches that might prevent the inhabitant's rejection: (1) a way of communication, which is specifically geared to the inhabitants, and, (2) A participatory process. While the last-mentioned strategy aims to provoke a feeling of being responsible, communication can raise the resident`s awareness.

Although the inhabitants still depend on the grid, the “self-generated” electricity will nonetheless be associated with the settlement’s independence. Due to the reduced dependence on electricity providers, a sense of autarky can arise [22]. This will release a certain feeling of pride among the residents, and they might be proud to be part of such a project. By comparing Kirchdorf Sued with the rest of Hamburg, it could finally exceed the norm in a positive way and hopefully gain social status.

6. Discussion

The analysis and the subsequent calculations have revealed that with the suggested PV system the settlement’s electricity demand can be covered by between 31% and 45%. Furthermore, the investment can be amortised within a reconcilable time span. If the produced electricity is directly used on-site, a win-win situation between the owner and the tenants can be created: the owner getting his investment back and with the tenants having a small share that could be invested in community projects. Moreover, such an installation would lead to an avoidance of about 131 tons of CO_2-equivalents per year. However, the numerical results must be regarded carefully. While some of the encountered numbers where congruent with the manifold sources, some others were widely differing. Particularly in the range of the social effects, many benefits would evolve. The PV system`s omnipresence could increase the inhabitant`s energy awareness. The valorized visual appearance of the building could help to reduce vandalism and simultaneously lead to proudness among the inhabitants. Furthermore, the neighborhood's character and especially its currently infamous reputation within the rest of the city might change to the better.

However, energy generation as well as, economic revenues and - generally speaking - monetary benefits can be calculated beforehand in a fairly precise way, non-monetary benefits have to be proven right in the long run. Even if this paper`s results are based on a simple calculation exercise and have no scientific relevance, they highlight the intervention`s potential from different points of view. Especially the social science perspective could be interesting for further investigations and supported with a representative survey as well as in-depth interviews.

Due to the neighborhood`s rather big size, a good chance to put the theory into praxis would be by starting a pilot project in a smaller scale. Having all stakeholders - and representatives - gathering for a round table discussion, would be a first step to start the process, followed by outlining the goals, finding the necessary funds, and elaborating a strategy to monitor and evaluate the benefits - and pitfalls - of the project in all its facets: technical, economic, ecological as well as social. After the implementation, the upkeep of the plant should stay - at least partially - in the hands of the community. The whole process (including monitoring and evaluation) should be documented in details, so that it could be used in the future for further large-scale projects.

By imagining the intervention on an extended scale - for example, if all the housing association’s suitable building envelopes would adopt this strategy - the effects could be multiplied. Furthermore, by considering the consequential potential for synergies, for example, a fully developed charging station network for electric vehicles all around the city, the impact would be even more impressive.

7. Conclusion

On our first site visit, the extensive, bare facade surface areas were the trigger for our chain of thought. We were wondering, if these perfectly south-facing walls were able to produce a significant amount of the current electricity demand and if it would be possible to have benefits that are not merely economic, but ecological and social as well.

Although the results are associated with some ambiguity, it was worth to look at the topic from different standpoints. The installation of solar modules is much more than “just” a technical issue and perfectly indicates that sustainable development is a wide field. In order to tackle the highly complex transition to post-fossil carbon societies, a broad variety of innovations is needed. Therefore multi-disciplinary thinking, research as well as practical implementation are needed to bring about progress in sustainable development.

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Effects of different reference study periods of timber and mineral buildings on material input and global warming potential

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Summary

In EN standards for life cycle assessment for buildings, time-related parameters such as the Reference Study Period (RSP) of buildings and Reference Service Life (RSL) of building products are only vaguely defined. Therefore authors often chose, depending on their background, arbitrary time-related parameters for LCA calculations.
This study examine the impact of different RSP on LCAs over 30, 50, 80 and 100 years with regard to the input of building material masses and associated global warming potential (GWP) relating to building construction and technical equipment. Life cycle assessments of buildings of different sizes and construction materials according to the method of EN 15978 (2012) are performed over RSPs of 30, 50, 80 and 100 years. For the RSL of building products the specifications of the German Assessment System for Sustainable Building (BNB) (last updated in 2011) and the Guideline Sustainable Building (2001) published by the federal institute for research on building, urban affairs and spatial development are applied. In summary the analysis show that the LCA results for a building depend on the RSP and the number of replacement of replaceable building components over the building's use stage. Looking at the different results between RSPs of 30 and 100 years, the importance of an adequate choice, or rather of uniform guidelines, for RSP and RSL in LCAs is obvious.

Keywords: reference study period, reference service life, life cycle assessment, use stage, replacement, EN 15978

1. Introduction

The new European standards EN 15978 (2012) for assessment of environmental performance of buildings and EN 15804 (2014) for environmental product declarations do not provide explicit data for the Reference Study Period (RSP) of buildings and Reference Service Lives (RSL) of building products, which are influential parameters on LCA results. Consequently, LCA studies of buildings are performed with arbitrary RSPs and RSLs, depending on the author's professional and geographical background. To cite few examples: the German Assessment System for Sustainable Building (BNB) defines 50 years for RSP in building certifications. Representatives of the mineral building material industries plead on meetings of the round table ‘sustainable buildings’ for longer RSPs of around 150 years. The latest Austrian study (2014) on building LCAs calculates over a RSP of 100 years [1]. *John (2013)* presumes in her current researches on CO_2 emissions in buildings RSPs of 60 years.[2] These discrepancies contributes to inconsistent LCA results in the building sector. Especially in building assessments time-related characteristics play a significant role, since components require maintenance, repair and replacement over the building’s use stage. With expansion of the use stage, which is determined by the RSP, the demand for maintenance, repair and replacement of components increases. This study analyses the EN standard 15978 concerning time-related characteristics and its scope of interpretation. On this normative base building LCAs are calculated focusing the building’s use stage (module B) and the effects of different RSPs.

2. LCA standards: Time-related characteristics in building assessments

The different stages of building assessment are shown in figure 1. Referred to EN 15978 the LCA results of the product stage (module A1-A3), the construction process stage (module A4-A5) and the end of life stage (module C1-C4) do not relate to time-relevant parameters. The relevant stage for measurable impact of the RSP is the use stage (module B1-B7). Due to replacement of components new material enters the system in module B which lead to a rising total input of building material masses and associated global warming potential (GWP).

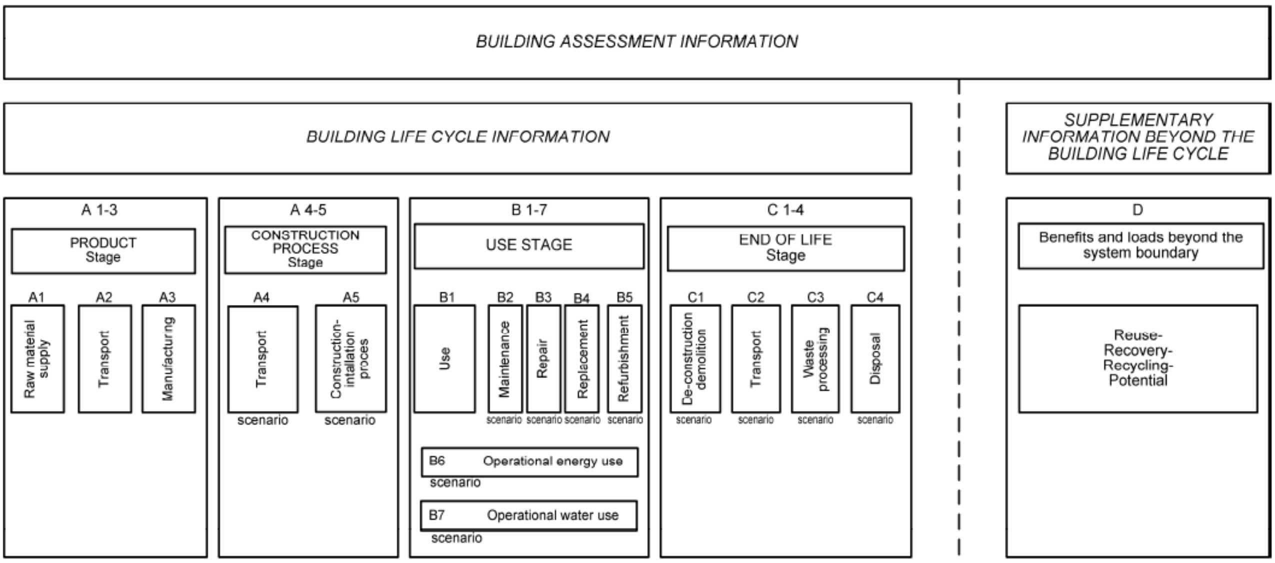

Fig. 1: Display of modular information for the different stages of the building assessment, EN 15978 [3]

The LCA standards apply several time-relevant terms in building assessment: Reference Study Period (RSP), Required Service Life (ReqSL), Estimated Service Life (ESL), Reference Service Life (RSL) and Design life. Exact definitions and normative references are listed in table 1. The column ‘level used’ specifies the level of application of the term in LCA context according to the standard. RSP, ReqSL and Design Life refer to the entire building system while ESL and RSL correspond to the building components, which are relevant for calculating the impact of the building’s use stage.

Table 1: Time-related terms and definitions in EN standards for LCA [3,4,5]

Term	**Abbr.**	**Reference**	**Definition**	**Level used**
Reference Study Period	RSP	EN 15978	period over which the time-dependent characteristics of the object of assessment are analyzed	Building
Required Service Life	ReqSL	EN 15978	service life required by the client or through regulation	Building
Design life	-	EN 15978	*service life* intended by the designer	Building
Estimated Service Life	ESL	EN 15978	service life that a building or an assembled system (part of works) would be expected to have in a set of specific in-use conditions, determined from reference service life data after taking into account any differences from the reference in use conditions	Component
Reference Service Life*	RSL	EN 15804 and ISO 15686-8	service life of a construction product which is known to be expected under a particular set, i.e., a reference set, of in-use conditions and which may form the basis of estimating the service life under other in-use conditions.	Component

*RSL is mentioned in EN 15978, but its definition is given in EN 15804

Regarding the building level, the definition for the RSP and ReqSL (‘required by the client […]’) provide a wide scope. The standard mentions that the default value for the RSP shall be the ReqSL of the building. If there are deviations, the values for impacts and aspects shall first be calculated for the ReqSL. If the RSP is shorter than the ReqSL, the quantified values of impacts of the use stage are reduced by the factor RSP/ReqSL. In case that the RSP is longer than the ReqSL, scenarios for refurbishment or demolition and construction of an equivalent new building shall be developed for the remaining time of the RSP. The procedure is described in detail in EN 15978, sec 7.3. [3] On component level, the values for the RSLs and the resultant ESLs are required. Via the factor method which procedure is described in ISO 15686-8, the ESL is calculated on base of the RSL.

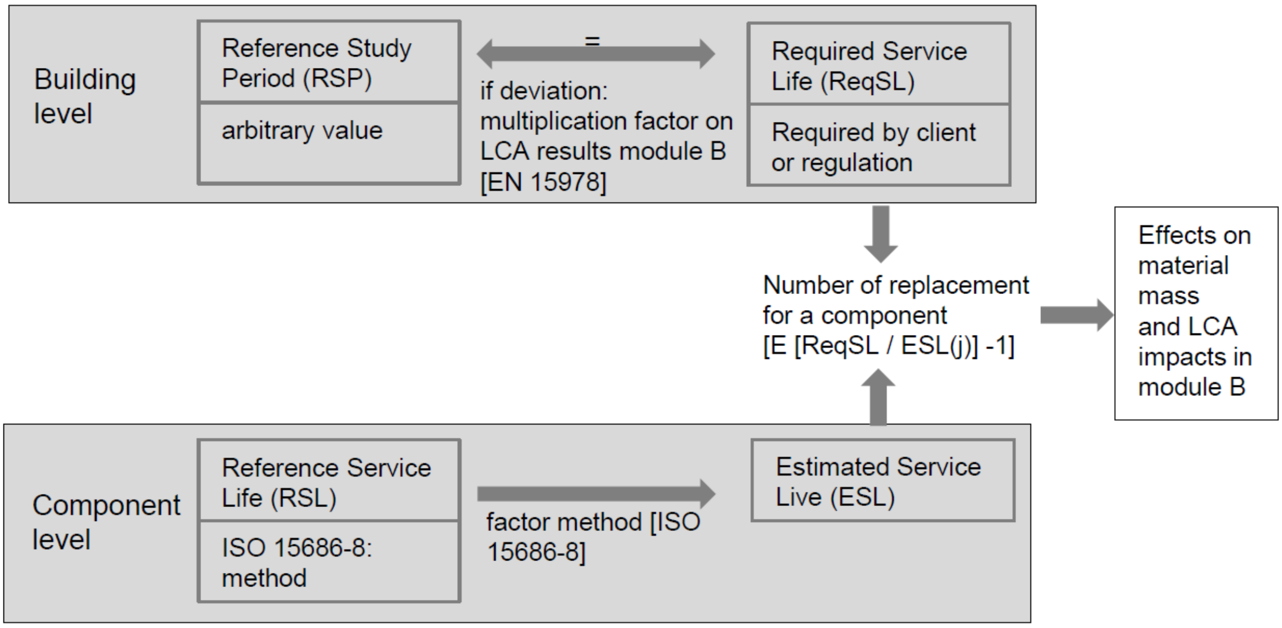

Fig. 2: Correlation of time-related characteristics in LCAs

Figure 2 shows the correlation of the time-relevant parameters which are necessary for building assessment.
The number of replacement is relevant for determining the building components and the associated material masses which are replaced in the building's use stage. The input material flows are elementary for the calculation of the LCA impacts. The number of replacement for replaceable components is given by the function [3]:

$$N_R(j) = E\,[ReqSL / ESL(j)] - 1 \qquad (1)$$

where

$N_R(j)$ is the number of replacements for product j;

E[ReqSL/ESL(j)] is the function that rounds up function ReqSL /ESL(j) to the higher integer value.

According to equation (1) the number of replacement in the building's use stage depends directly on the parameters ReqSL and ESL.

3. Methodology: System boundaries

3.1 Analysed buildings and frame conditions

The analysed buildings comprise the use categories small residential buildings, which are single-family houses (SFH) with up to two floors and large residential buildings which are multi-family houses (MFH) with three floors and more. All buildings are realised objects and their year of erection was between 2006 and 2014. In total 22 buildings were examined, 12 SFH and 10 MFH which have various construction methods. They are classified in three groups: mineral buildings (brick, concrete with thermal insulation composite system), timber frame buildings and solid timber buildings. The size of the buildings varies between 130 m² gross external area (GEA) for SFHs and 6150 m² GFA for MFH. (see table 2).
All buildings were calculated without basement but including foundations in order to overcome the huge influence of basement on the results. Outdoor facilities on the building site are also unaccounted. The energetic performance of the buildings at least comply with EnEV 2009 or better, hence all analysed buildings have an approximately identic energetic standard. The buildings are analysed with regard to the input of building material masses and the associated GWP as one of the most researched indicators in LCA calculations. All construction material and technical equipment required over the RSP was considered. The results were assessed by the functional unit of one m² GEA and one m² GEA for one year of the RSP.

Table 2: Overview of use categories and classification of construction types

Use category	Number of floors	GEA [m²]	Number of			
			mineral	timber frame	solid timber	Total
Small residential buildings	2	130-380	4	5	3	12
Large residential buildings	3-8	700-6150	4	3	3	10

LCA calculations were done with the LCA-tool LEGEP [6] that bases on the German open-source database Oekobau.dat published by the federal ministry for the environment, nature conservation, building and nuclear safety [7]. The Oekobau.dat is regularly updated, at the time when the calculations were done, the prevailing version was Oekobau.dat 2011.

3.2 Time-related characteristics: Reference Study Period and Reference Service Life

The German Assessment System for Sustainable Building (BNB) defined the RSP over 50 years for building certification as a result of a political consensus [8]. In order to illustrate the effects of different RSPs, realistic periods of 30, 50, 80 and 100 years were chosen for this study.
For the RSL of the building components the specifications of the BNB system were applied [8]. The federal institute for research on building, urban affairs and spatial development (BBSR) published a table titled ‘Service life of building elements’ which provides RSL of building components for the defined building-related assessment period of 50 years based on former studies, which rest upon bibliographical references and empirical values from experts [9,10,11]. The final version of the BNB table ‘Service life of building elements’ was reviewed again by industry associations, research institutions and other experts [11]. For technical building systems the VDI 2067 provides relevant data.
Building components with RSL of more than 50 years are marked in the BNB table with ≥ *50 years*. Since this study assesses also buildings with RSPs of 80 and 100 years, the RSL for components ≥ *50 years* are in dependence on the former guideline ‘Sustainable Building’ from 2001 [10]. As the effort for replacing the primary construction (walls, floors, etc.) within the ReqSL of a building is not realizable in practice, this study conditions that the primary construction is not replaced over its RSP. Table 3 shows the linked number of replacement with minimum and maximum values, depending on the material type. Replacement does not occur if the RSP ends within the following three years.

Table 3: Overview of number of replacement used in LCA calculations [6]

Construction component	number of replacement							
	30 years RSP		50 years RSP		80 years RSP		100 years RSP	
	min	max	min	max	min	max	min	max
external wall construction	0	0	0	0	0	0	0	0
external wall coating &cladding	0	3	0	5	0	9	0	12
exterior doors	0	2	1	3	1	6	2	8
exterior windows	0	1	0	1	0	3	0	3
internal wall construction	0	0	0	0	0	0	0	0
internal wall coating & cladding	1	1	2	3	3	5	4	6
interior door & coating	0	4	0	7	1	11	1	14
ceiling construction	0	0	0	0	0	0	0	0
ceiling coating & covering	0	3	0	5	0	9	0	12
roof construction	0	0	0	0	0	0	0	0
roof coating & covering	0	2	0	3	1	6	1	8

3.3 Calculated modules over the building’s life cycle

According to EN 15978, the system boundary for a new building shall include the building life cycle as shown in figure 1. A basic factor for the quality of LCA results is the integrity of the underlying database. At this stage, the used Oekobau.dat 2011 does not provide sufficient data for the consideration of all modules, therefore only the product stage (module A1-A3), replacement in the use stage (module B4) and waste processing and disposal in the end of life stage (module C3-C4) were calculated (see table 4). EN 15978 demands the separation of module D which is currently not possible due to insufficient data. At this point of time, the results of module D are inevitably integrated in module C. The operational energy use (module B6) which is defined by the EnEV was left aside for this study since the analysed buildings are functionally identical. In doing so the focus of the LCA results is on the material flows in module B which makes it clearer to compare the input of building material masses and the associated GWP.

Table 4: Overview: calculated modules

Module	**Description**	**Data and origin**	**Calculation**
A1-A3	Product stage	Oekobau.dat 2011	Yes
A4-A5	Construction process stage	No	No
B1	Installed products in use	No	No
B2	Maintenance	No	No
B4	Replacement	BNB system	Yes
B6	Operational energy use	EnEV	No relevance, since functionally identical
B3,B5,B7	Repair, Refurbishment, Operational water use	No	No
C1-C2	Deconstruction, Transport	No	No
C3, C4	Waste processing, disposal	Oekobau.dat 2011	Yes
D	Reuse, recovery, recycling potential	No separate data available, in Oekobau.dat 2011 integrated in module C	in module C

4. LCA results

4.1 Overview life cycle phases

The LCA calculations show that the influential stage on LCA results is module B. With extension of the RSP the absolute material input increases over m² GEA. The results of SFH and MFH have the same tendency, with lower values per m² in SFH buildings.

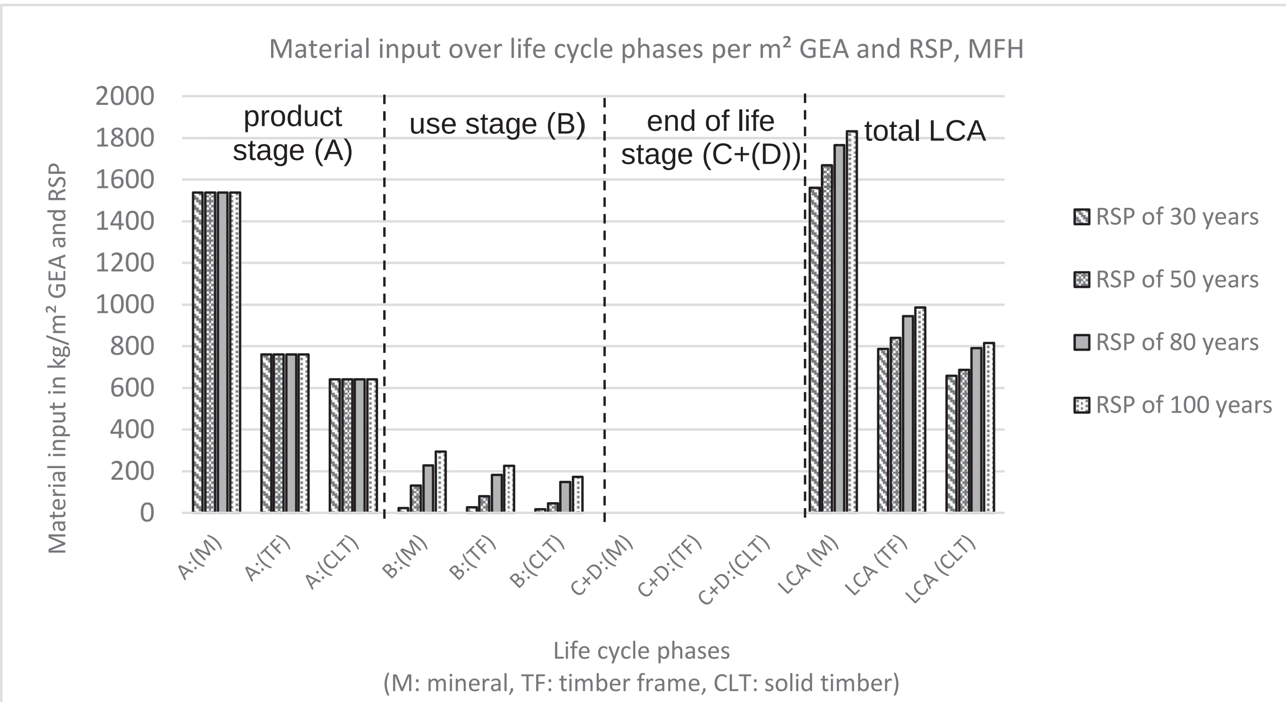

Fig. 3: Material input over life cycle phases per m² GEA and RSP, MFH

Module A and C are independent from the RSP as the mass input and the GWP emissions for each construction type are identic over 30, 50, 80 and 100 years (fig. 3 and 4). The end of life stage (module C) has no material input. Due to higher mass of mineral buildings in stage A1-3 material input is significant stronger. Wood constructions have lower GWP values than mineral buildings due to carbon storage and substitution effects. [12]

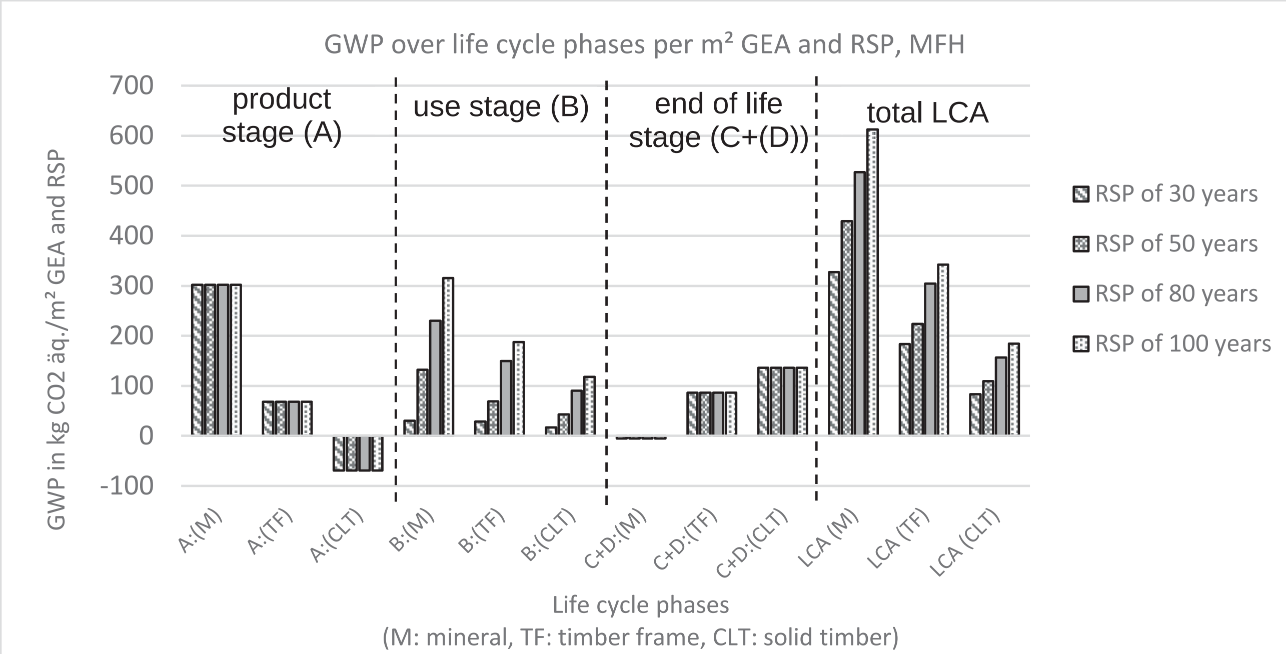

Fig. 4: GWP over life cycle phases per m² GEA and RSP, MFH

Looking at the relative values of input masses and GWP per m² GEA and year, it is obvious that with extension of the RSP, less material respectively GWP emissions per year over the total life cycle accrue. Furthermore, the influence of the RSP in mineral buildings is for the indicator GWP stronger than in timber framed or solid timber buildings. Figure 5 illustrates that there is hardly a difference between RSPs of 50, 80 and 100 years over the total life cycle of solid timber buildings. The different effects are caused by the use stage. Differences of other indicators in LCA calculations like AP, ODP, etc. have to be observed in a next step.

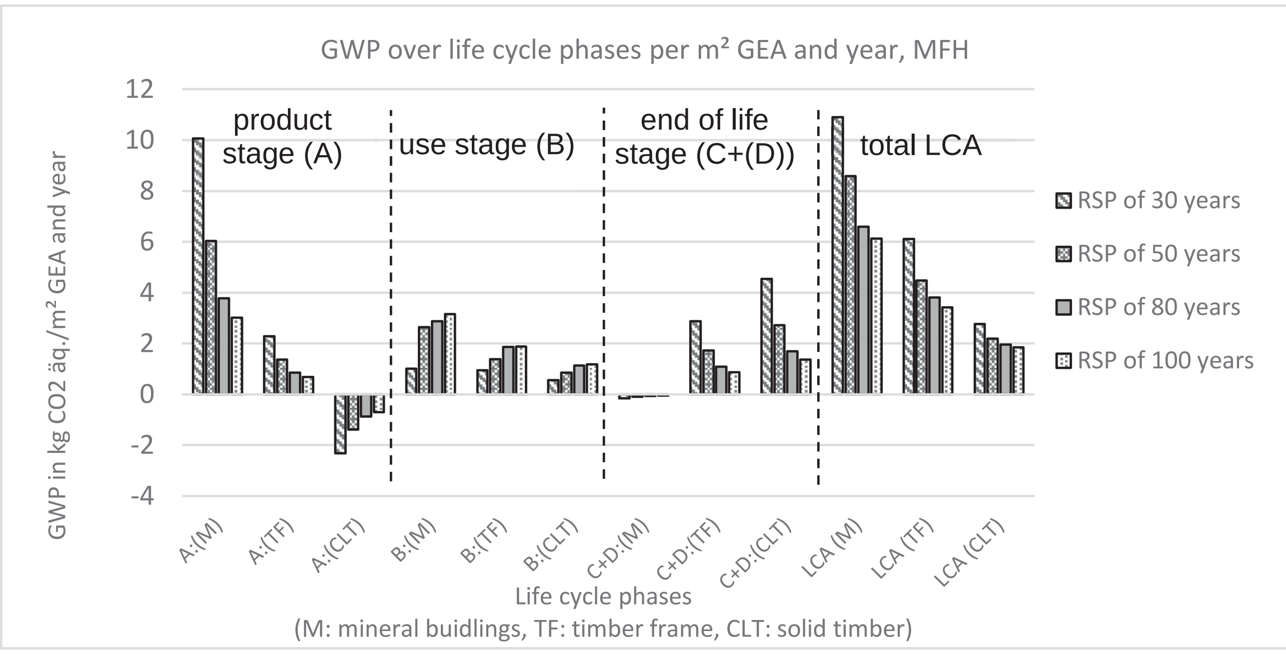

Fig. 5: GWP over life cycle phases per m² GEA and year, MFH

Focusing on the use stage, the input material masses and the associated GWP emissions depend on the construction type of the building, the number of replacement and the point in time of replacement within its RSP. From a sustainable point of view, the best point in time for replacement of a building component would be when its RSL comply to the remaining RSP. Since the analysed RSPs of 30, 50, 80 and 100 years are arbitrary chosen numbers, it occurs that a building component requires replacement just a few years before the building's RSP expires. At the end of the RSP, the building including all components, independent of their RSLs, pass through the end-of-life stage.

4.2 Building construction and technical equipment in the use stage

The percentage of GWP emissions of technical equipment in relation to the total GWP emissions of a building category is approximately identic over RSPs of 50, 80 and 100 years. Over a RSP of 30 years the percentage is slightly lower (fig. 6). Variations in the building categories are due to different installed heating systems. Depending on the technical system installed more or less technical equipment and replacement are required. Some buildings e.g. have a solar plant what leads to higher GWP emissions.

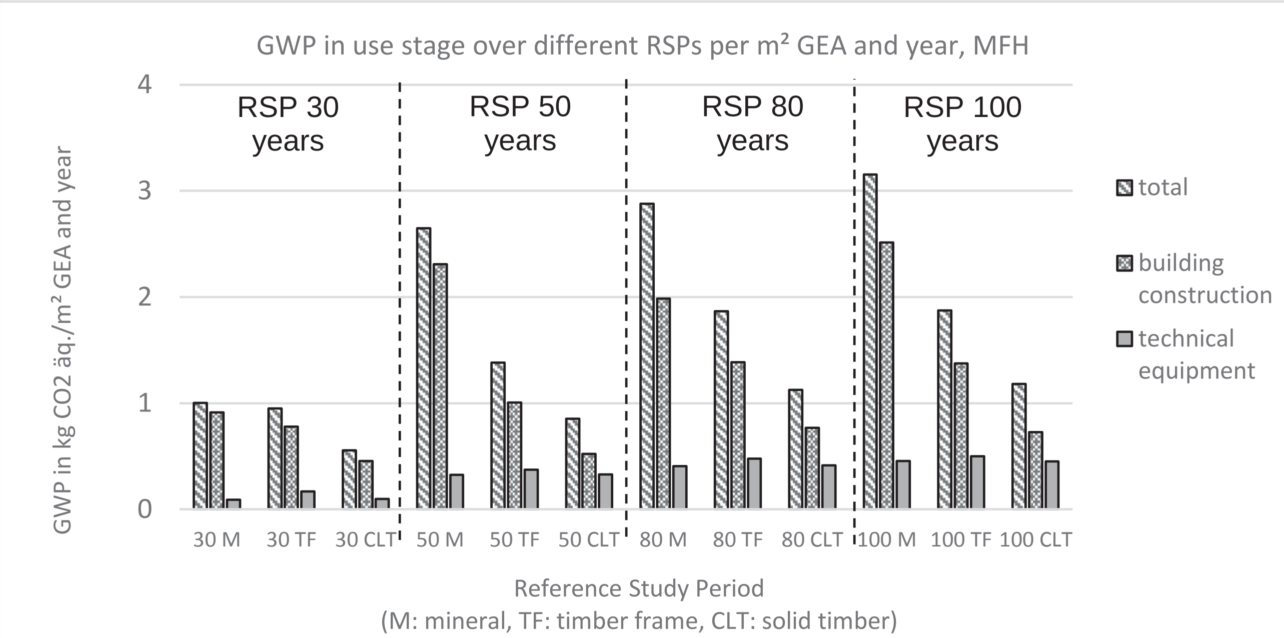

Fig. 6: GWP in use stage over different RSPs per m² GEA and year, MFH

5. Discussion

The variance of the results illustrate the influence of the RSP on a building LCA, especially on the building's use stage. The RSP is a crucial parameter for the number of replacement of components during the use stage.
EN 15978, the current standard for LCA performances of buildings, does not provide clear specifications in this case. Instead it distinguishes between 3 cases. 1. The most commonly used case is that the RSP and the ReqSL are the same. 2. If the RSP is shorter than the ReqSL, the quantified values of impacts of the use stage are reduced by the factor RSP/ReqSL. 3. If the RSP is longer than the ReqSL, scenarios for refurbishment or demolition and construction of an equivalent new building shall be developed for the remaining time of the RSP. The description for this case is not clear, since there is no specification on how to develop a new equivalent virtual building. Besides it is questionable if in reality a LCA would be performed for a RSP which

exceeds the actual ReqSL. In this study it was assumed that the primary construction, independent of the used material, is not replaced which means that the RSLs of the building components in the primary construction are adapted to the RSP. Looking at the total LCA results in chapter 4, the question arises whether it is reasonable from an ecological point of view, to extend the RSP and the ReqSL of a building and having higher replacement efforts instead. In return the overall LCA values decrease when using a building over a longer life cycle. This assumes that the durability of the materials in the primary construction is given over the RSP.
Besides the technical durability of building components which significantly influences the RSLs of building products, the factor of unpredictability of fast changing user requirements must also be considered. Such incidences in the use phase could lead to shortened RSLs of building components and higher numbers of replacement than primarily assumed. However these effects are not reliably quantifiable since the use and operation of a building is individually formed by its residents and cannot be foreseen. Consequently, so far it is only possible to focus on technical use conditions of buildings components in the development of average use scenarios. Nevertheless it should be kept in mind that user requirements change over time and from an economic point of view building industries adjust to the changing market situation. It should be discussed to which extent both, technical and user aspects can be respected in the determination of RSLs.
Note: At this time the results of the end-of-life stage are not yet compliant with the standard EN 15978 since it is not possible to separate the datasets of Oekobau.dat 2011 in module C and D. The new version of the database, Oekobau.dat 2015, is in process. If module D is considered separately, module B will also change since the end-of-life stage of the removed component is also part of module B. The amplitude of the changes in module B, C and D depends on the material type.

6. Conclusion

Building LCA results vary with the RSP. Generally speaking, the longer a building is used the less material input and the less GWP emissions over its functional unit of one m² of GEA for one year of the RSP are accrued. The impacts relate to the number of replacement of a building product within its RSP, which is determined by the RSL of the building product. In this respect, the influence of technical equipment does not change significantly over different RSPs.
The results of the performed LCAs in this study point out the demand for clear specifications of time-related parameters to achieve comparability of building LCAs. The EN standard 15978 (2012) only vaguely describes how to determine the RSP, ReqSL and RSL of buildings respectively of building components. Furthermore the results of the study illustrate that LCA results can be optimized by better synchronization of the RSP and the point in time of replacement in the use stage. Subject to the condition that the RSL of building components and the ReqSL of the building match with reality. Therefore average scenarios for the use phase have to be developed which need to be adapted regularly to new conditions (e.g. optimized product quality). Consideration of implementing both, technical aspects and changing user requirements in RSL determinations should be made.

7. Acknowledgements

The idea for this study came up within the scope of the research project *Greenhouse gas balances for timber buildings - Implementation of new requirements for life-cycle assessments and* *calculation of empiric substitution factors* funded by the Waldklimafonds. The authors gratefully acknowledge the assistance of all concerned. Some of the LCA-data used was calculated by Holger König for the project named above [13].

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Effects of energy efficiency measures in district-heated buildings on energy systems

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Summary

The primary energy savings depend on both the final energy savings and the energy efficiency of the supply system. In this study, we evaluate primary energy savings of different energy efficiency measures in a multistory district-heated building in Sweden. We consider various locations of the building with different district heat production systems (DHS) of different scales, technical characteristics and heat-load profiles. We show that the primary energy savings of the energy efficiency measures vary with the type of measure and with the type of energy supply systems. The energy efficiency measures give large final energy savings but their primary energy savings vary significantly. Of the energy efficiency measures, the measure that gives electricity savings but increase the use of district heat is the most primary energy efficient in relation to the final energy savings. Heat savings in buildings connected to small-scale DHS using heat-only boilers is more primary energy efficient than that in buildings connected to medium- and large- scale DHS using combined heat and power units. Evaluation of energy efficiency measures for district-heated buildings requires a systems perspective where the final energy savings in buildings are matched to the actual energy supply systems.

Keywords: energy efficiency, district-heated building, primary energy use, district heat

1. Introduction

Significant changes are essential for the building sector to achieve the EU-2050 objective of greenhouse gas emission reduction [1]. End-use energy efficiency measures could improve buildings performance by minimizing final energy use. However, the primary energy savings due to energy efficiency measures depend on the energy supply systems of the buildings [2] [3]. Therefore, both energy demand and supply of buildings need to be considered in an integrated way.

Heat for space and hot water heating in buildings is significant in regions with cold climate such as in the European Union (EU). Statistics show that fuels for heating buildings constitute approximately 23% of the total primary energy use in the EU-27 [4]. Heat for buildings is normally at low temperature and can be deployed by various technologies and energy sources [5] [6]. Hence, this type of heat demand gives several opportunities to develop heating systems based on a more sustainable energy infrastructure.

District heating is a common system for heating buildings and exists at different scales and technical setups, depending on the local settings such as climatic conditions, energy performance of buildings and the sizes of the communities they serve. In the EU, with approximately 6000 existing district heating systems, the potential expansion is large [4] [7]. In Sweden, more than 450 district heating systems [8] provided 56% of the total energy use in residential buildings and non-residential premises in 2011 [9].

District heat production technologies vary with the scale of the systems. In small-scale district heating systems, heat is normally produced by heat-only boilers [8] while in large-scale DHSs, heat is often partly produced in combined heat and power (CHP) production units. In CHP units the amount of cogenerated electricity depends on the produced district heat. As a result, a change in heat demand at district-heated end-users can influence the amount of cogenerated electricity and hence the overall electricity production system, for example the electricity production in standalone power plants.

Multi-apartment buildings, typically located in high-density residential areas, dominate the district heat use. For example, in Sweden about 84% of the floor area of apartment buildings are heated by district heat [10]. These buildings consumed about 50% of the total district heat production in Sweden in 2011 [9]. More than half of the Swedish multi-apartment buildings were constructed between 1950 and 1975 with varying size, design, materials and construction techniques [10] and have a huge potential for energy efficiency improvements. Such improvements can be fulfilled by different combination of approaches with regard to building type.

The energy renovation of existing buildings is crucial to develop an energy-efficient built environment. Existing buildings are of different types with different energy performances and located in different regions giving different specific energy demands [11]. As a result, the potential final energy savings of different energy efficiency measures varies for different building types [2] [3] [12] [13]. Some energy efficiency measures may not reduce a building's heat demand, such as switching to energy-efficient electric appliances, but instead increase the heat demand [3] [12]. As a consequence, effectiveness of energy efficiency measures goes beyond the local heat supply system of which a building is connected. Therefore, a system analysis is needed to quantify the primary energy savings due to energy efficiency measures and to understand the effectiveness of energy efficiency activities in buildings.

In this study, we evaluate effects of different energy efficiency measures in an existing typical district-heated building. We consider different site-specific contexts including different locations of the building in Sweden and various district heating systems in scale, technical setup and heat-load profile. We analyze how the primary energy use is changed as a consequence of energy efficiency measures, taking into account the hourly variation of final energy savings and actual hourly operation of different district heat production units.

2. Methodology

2.1 Case-study building and energy efficiency measures

We use an existing multi-apartment building constructed in 1995 in Växjö, Sweden as a case-study building. This building has 4 stories and 16 apartments with a total heated floor area of 1190 m². The building is currently connected to the local district heating system. Different energy efficiency measures for this building have been analyzed and discussed [2] [3]. Table 1 lists all the energy efficiency measures explored for the case-study building. In this study, we group these measures into three categories, depending on how final energy use is influenced: (a) measure that reduce district heat demand: improvement of water tap and building envelope; (b) measure that reduce district heat demand but increase electricity demand: ventilation heat recovery; and (c) measure that reduce electricity demand but increase district heat demand: efficient household appliances.

Table 1: Energy efficiency measures

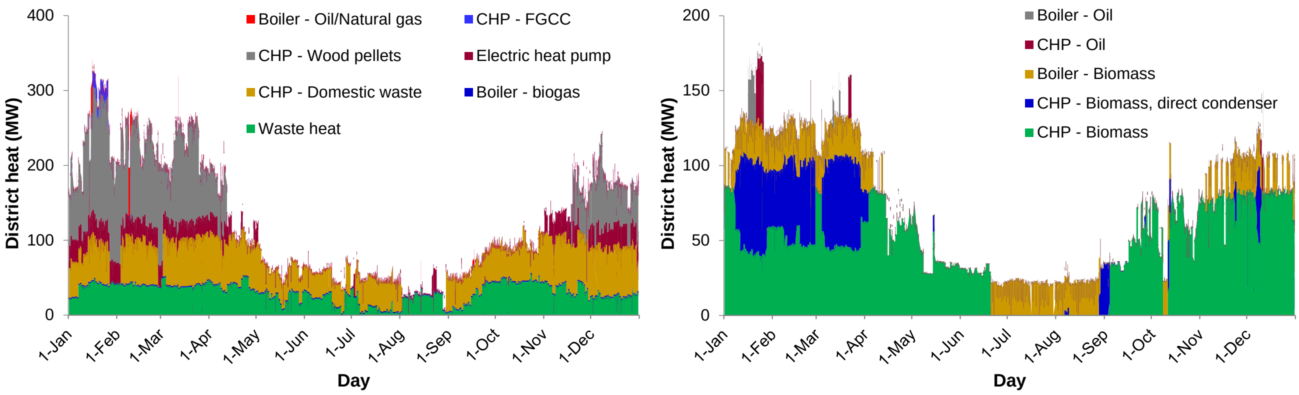
Description	Effects of improvement
• Improved water taps	Reduced hot water used by 40%
• 10 cm additional mineral wool insulation added to the roof	U-value from 0.13 to 0.09 W/m2 K
• Windows replaced by triple-glazed units (low e-coating and krypton filled)	U-value from 1.9 to 0.90 W/m2 K
• Doors replaced by triple-glazed units (low e-coating and krypton filled)	U-value from 1.19 to 0.90 W/m2 K
• 25 cm additional mineral wool insulation added to external walls	U-value from 0.20 to 0.10 W/m2 K
• Incorporation of ventilation heat recovery unit with 80% efficiency	Reduced ventilation heat loss by 57%
• Electric efficient household appliances	Reduced household electricity by 44%

2.2 Heat and electric supply systems

The district heating systems in the municipalities of Helsingborg, Växjö and Ronneby, corresponding to three different district heat production scales, are considered (Table 2). In each system, different district heat production units of different technologies are used. We base our calculation on the hour-by-hour operation data of the different units in each system in 2013 (Fig. 1), which is considered as a normal operating year.

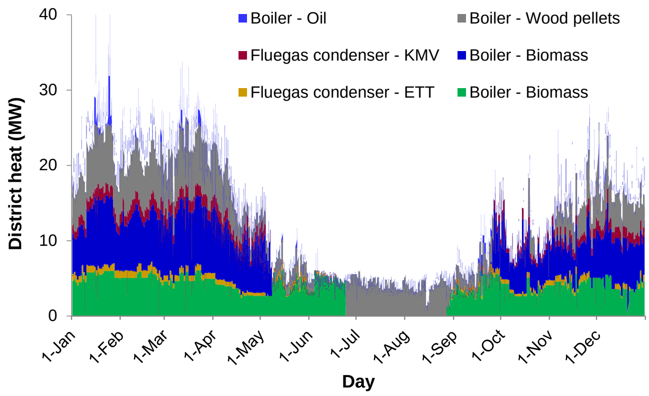
Table 2: Annual heat production and peak demand of different considered district heating systems

District heating system	Annual heat production *(GWh)*	Peak heat demand *(MW)*
• Helsingborg	1100	340
• Växjö	630	180
• Ronneby	110	33



a.) Helsingborg

b.) Växjö



c.) Ronneby

Fig. 1 District heat production in Helsingborg, Växjö and Ronneby in 2013 given hour-by hour

2.3 Supply- and demand-side interaction in energy system

Changes in the district heat demand influence the operation of the marginal district-heating unit that may vary during the year. In this study, we assume that a changed heat demand influences the operation of marginal district heat production unit immediately if the changed heat demand is in the range of installed capacity of the marginal unit. To evaluate the changed primary energy use of district heat production units due to a changed district heat demand, we assume that the performance of the used technologies follow the specification in Table 3.

Table 3. Performances of district heat and standalone power production units. The data are based on the lower heating value (LHV) of fuels.

Technology	Reference capacity (MW_{heat})	Conversion efficiency (%)	
		Heat	Electricity
Heat-only production			
- Biogas[a]	25	97.0	-
- Electric heat pump[a]	25	280.0	-100
- Fuel oil[b]	50	90.0	-
- Wood chips[a]	12	108.0	-
- Wood pellet[d]	50	89.0	-
CHP plants			
- Gas turbine combined cycle, Fuel oil/Fossil gas[a]	10-100	41.0	41.0
- Steam turbine, Domestic waste[c]	91	86.0	19.0
- Steam turbine, Fuel oil[b]	80	56.0	34.0
- Steam turbine, Wood chips[c]	83	77.0	28.0
- Steam turbine, Wood pellet (rebuilt from coal-based)[d]	129	55.0	34.0
Standalone power plants			
- Steam turbine, Coal[e]	400	-	45
- Gas turbine combined cycle, Fossil gas[f]	420	-	58

[a] [14]; [b][15]; [c] [16]; ; [d] Assumption, based on [15] with the same performance as coal-based unit [14] ; [e] [17]; [f] [18]

The main purpose of a DHS is to produce heat and the amount of cogenerated electricity in CHP units depends on the demand for district heat over the year and the district heat production system as well as the monetary value of cogenerated electricity. Hence, a changed district heat demand may influence the potential amount of cogenerated electricity in CHP units. If the amount of cogenerated electricity changes, it influences the overall electricity production system in the region.

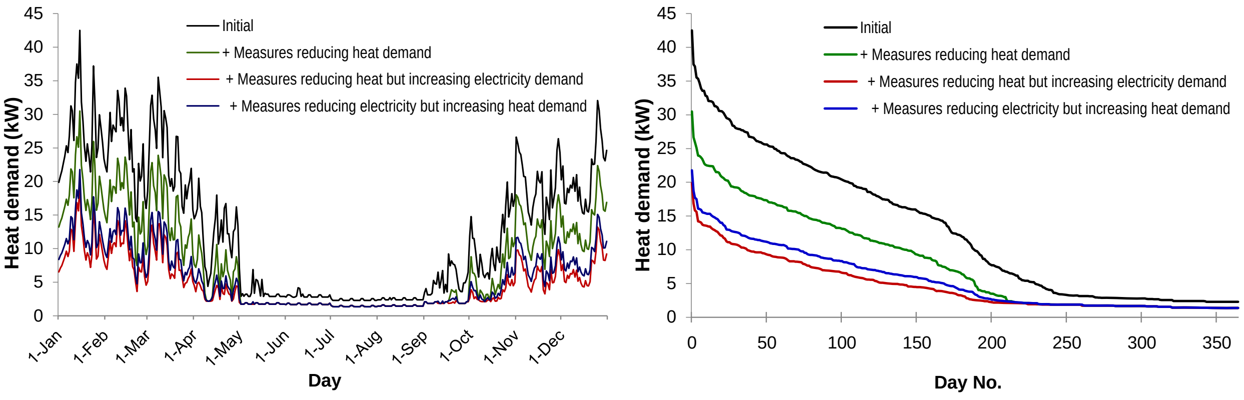
Currently, the Nordpool trading system is used for the Nordic grid, involving different electricity producers with a mix of production units operating based on the marginal costs to satisfy the varied electricity demand. Standalone power plants based on coal and fossil gas may have the lowest short-term and long-term marginal costs, respectively [19], depending on several factors such as fuel prices and policy measures, as well as technological development and on integration of power systems within the EU in a longer time perspective. Also, energy efficiency measures have a long lifetime and may influence a building's heat demand during its remaining lifetime of about 50 years. Hence, the uncertainties are large and depend on how cogeneration of electricity affects the overall electricity production system over time. In our analysis, we assume that the marginal changes of coproduced electricity from DHSs are balanced by standalone power plants using either a.) coal-based steam turbine (CST), or b.) fossil gas turbine combined cycle (FGCC) (Table 3). The change in the overall electricity system is then credited or debited to the district heat production. That means that the primary energy use for district heat production with CHP units is estimated based on the subtraction method [20].

District heat is supplied to a building via a heat distribution system and a district heat substation at the building, resulting in heat losses. However, heat savings in a building have a minor influence on these heat losses and are not considered in this study. However, the distribution losses of electricity are proportional to the consumed electricity. Therefore, we assume a transmission and distribution losses of electricity of 7%, which is based on the Swedish average in 2011 [9], when the electricity use is changed.

3. Results

3.1 Final energy savings

Table 4 shows final energy savings for the different types of energy efficiency measures. The overall annual savings of heat and electricity are 65.6 MWh and 19.0, respectively. Overall, the district heat demand of the building is reduced from 114 MWh to 48.5 MWh per year or by 57%. Fig. 2 shows the final heat use hour-by-hour before and after applying the grouped energy efficiency measures.



a.) *b.)*

Fig. 2 Hour-by-hour final heat use profiles during the year (a) and arranged in a descending order (b) of the case study building before and after applying the grouped energy efficiency measures

Table 4: Final energy savings for grouped energy efficiency measures

Measure	Savings (MWh)		
	Heat	*Electricity*	*Total*
- Measures reducing heat demand	42.2	-	42.2
- Measures reducing heat but increasing electricity demand	30.5	- 4.8	25.7
- Measures reducing electricity but increasing heat demand	-7.6	23.8	16.3

3.2 Operation of district heat production units

Fig. 3 shows the effects of a heat saving measure in the case study building if the building is connected to the DHS of Helsingborg. If a CHP unit is operated as a marginal district heat production, the heat savings reduce the amount of cogenerated electricity and a reference standalone power plant has to compensate for the reduced cogenerated electricity. Therefore, the primary energy savings due to the heat savings at the building are linked to the district-heat production system and the reference condensing power plant.

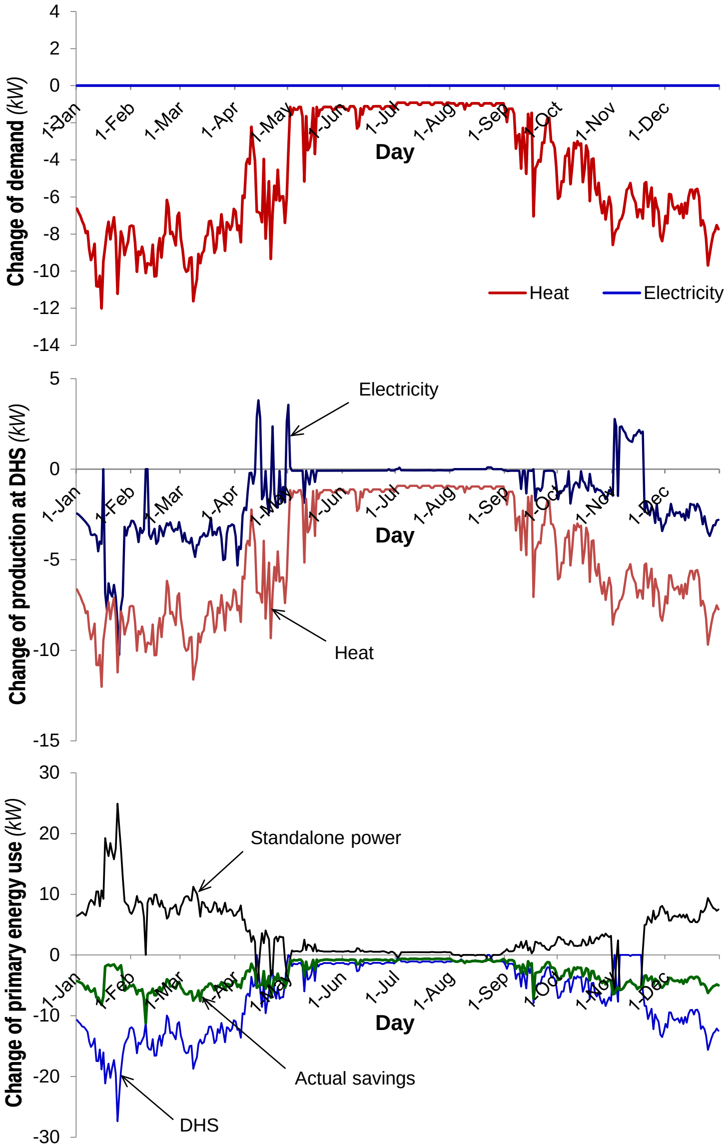


Fig. 3 Changed of energy supply systems versus changes of final energy demand at the district-heated building

3.3 Primary energy savings

Fig. 4 shows the annual primary energy savings of the grouped energy efficiency measures cumulatively. In general, the total primary energy savings are higher than the total final energy savings. However, the variation is large for a specific measure and partly depends on the DHS.

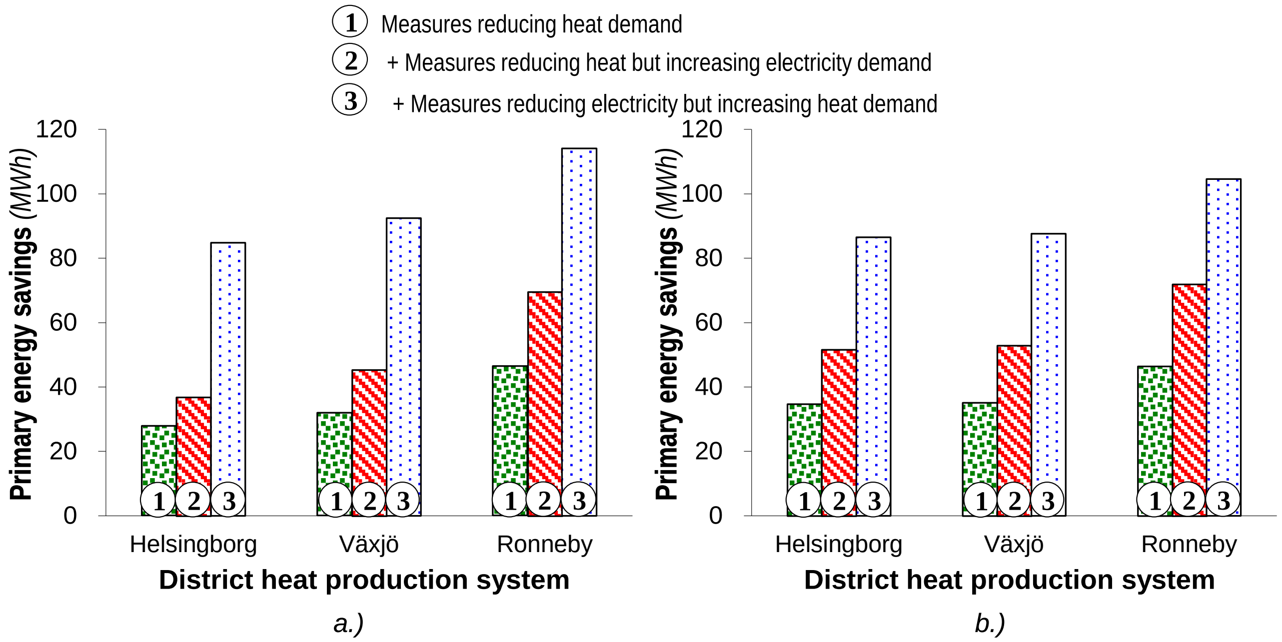


Fig. 4 Primary energy savings of cumulatively applied energy efficiency measures in the building with different district heat supply systems if a.) CST is used as a reference standalone power plant and b.) FGCC is used as a reference standalone power plant

Fig. 5 shows the ratio of primary and final energy savings for the different grouped energy efficiency measures for the different DHSs. This ratio reflects the primary energy efficiency of a measure and depends on final energy savings and the type of energy supply system. If the ratio is one, the primary and final energy savings are equal (see dotted line in Fig. 5).

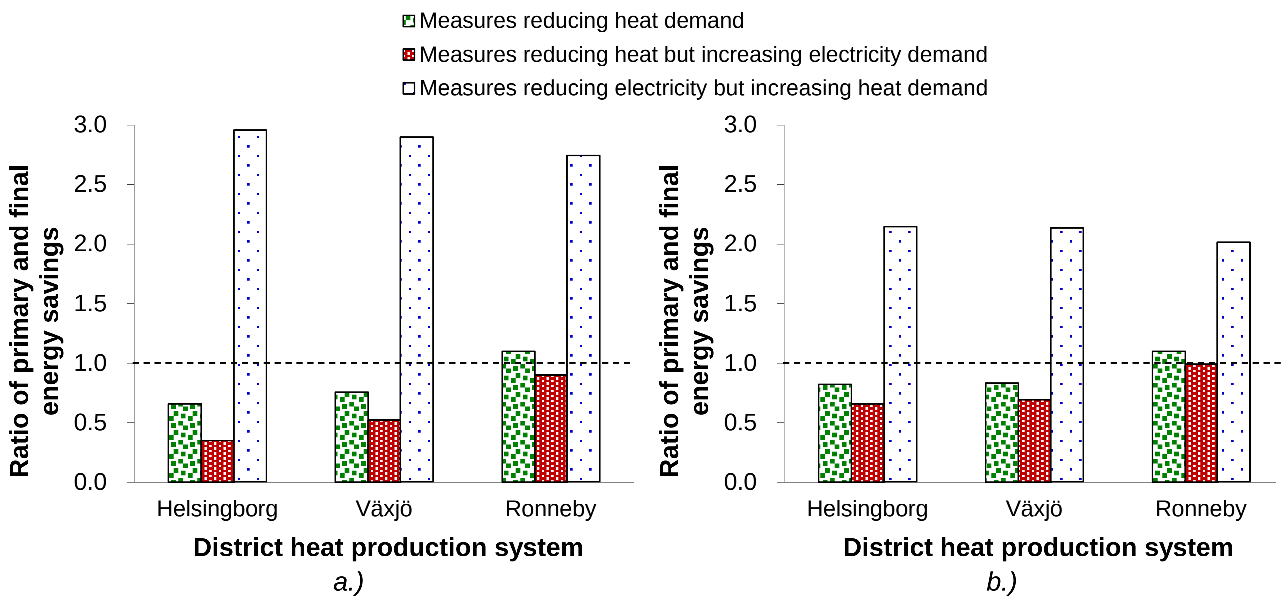


Fig. 5 Ratio of primary and final energy savings for different energy efficiency measures in the building with different district heat supply systems if a.) CST is used as a reference standalone power plant and b.) FGCC is used as a reference standalone power plant

Of the considered measures, measures reducing the electricity demand but increasing the district heat demand give the highest primary energy efficiency (primary energy savings per unit of final energy savings) whereas measures reducing the heat demand but increasing the electricity demand give the lowest primary energy efficiency. Also, the final heat savings give larger primary energy savings in the small-scale DHS using heat-only boilers than in large-scale DHSs using CHP units.

4. Discussion and Conclusions

Energy renovation of the existing building stock is crucial to develop an energy-efficient built environment. However, this study showed that the primary energy savings could be higher or lower than the final energy savings in district-heated buildings. The primary energy efficiency (primary energy savings per unit of final energy savings) of energy efficiency measures depend on the both the specific energy efficiency measures and the energy supply systems. Of the considered measures, measures reducing electricity but increasing the heat demand give the highest primary energy efficiency. The primary energy efficiency will increase if the savings result in increased operation of CHP units at the DHS, as coproduced electricity is assumed to replace electricity in standalone condensing power plants which have lower system efficiency. Hence, the primary energy efficiency in such a case is affected by the assumed performance of replaced electricity, and improved performance will reduce the primary energy efficiency. Measures reducing the heat demand but increasing the electricity demand give the lowest primary energy efficiency. The total final heat and electricity savings are high if all the energy efficiency measures are considered, 57 and 44%, respectively.

The scale of the DHS influences the primary energy efficiency of different energy efficiency measures. The primary energy efficiency of heat savings is higher for buildings connected to a small-scale DHS with heat-only boilers than those connected to a large-scale DHS using CHP units. Also, it is more primary energy efficient to reduce electricity use and increase heat use in buildings connected to a large-scale DHS with CHP units in contrast to those connected to a small-scale DHS using heat-only boilers.

In this study we assumed that a changed heat demand directly and immediately influence the marginal district heat supply units operating with a fixed performance. This is a simplification. In fact, the intermittent and the part-load operation of district heat production units may marginally influence the performance of them. Also, for the systems having thermal storages as in the case of Helsingborg and Växjö systems, the operation of district heat production units may depend on the operation of the thermal storages. Hence, a marginal changed heat demand could be delayed by using a themal storage to shift the district heat production to units operated under different performances.

Evaluation of energy efficiency measures in district-heated buildings requires a systems perspective where the final energy savings in buildings are matched to the energy supply systems. Analysis of primary energy savings requires a comprehensive approach, of both the demand side considering the time interval of the savings, and the supply side considering the configurations and operation of different district-production units including the potential impact on the overall electricity production system. In this study the energy savings were calculated hour-by-hour and matched against the existing district-heat production in 2013 in Helsingborg, Ronneby and Växjö hour-by-hour.

Even though this study considered specific cases of energy supply system, the results could be elaborated in wider perspectives. The three case study DHSs represent different contexts of district heat production from simple heat-only boilers to a more sophisticated one involving different district heat production units of different technologies and fuel types. Also, the two cases of reference marginal electricity may reflect the short- to the long-term situation of the existing European power system [19]. Therefore, the analyzed results represent various situations and could be used to elaborate the cost effectiveness of energy efficiency measures in district heated buildings.

5. Acknowledgements

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Embodied impacts in stakeholder decision-making in the construction sector

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Summary

Increasing attention is being paid to embodied impacts of buildings and their products to reduce the overall impact of the construction sector on the environment as part of an effective life cycle approach to address the challenge. The question is how to incorporate them into the design and decision-making processes in the sector. Here, the different roles and decision-making contexts of different stakeholders in the construction supply and value chains are presented, and some guidance on how the key stakeholders can contribute to reducing the overall embodied impacts in the sector is provided. Specific opportunities and directions for further development are identified.

Keywords: embodied energy, embodied greenhouse gas emissions, sustainability, life cycle, building

1. Introduction

Until recently, building sustainability assessment, in general, and energy-efficient building design and assessment, in particular, have not fully included the embodied impacts of building and construction materials. The strong focus on issues of improving energy efficiency in buildings during occupancy or the operational phase has progressively reduced energy use and related greenhouse gas (GHG) emissions. However, this has only highlighted further the increasing importance of the impacts associated with the other phases of a building's life cycle, from material production to building construction, maintenance, and end-of life (i.e. the embodied impacts). For example, considering the European requirement for all new buildings to be nearly zero energy buildings by 2020 [1], this means that in the near future embodied energy may constitute close to 100% of a building's total energy consumption in Europe. At the same time, the need to meet the target of net-zero operational energy will increase the embodied energy by requiring, for example, the increasing use of insulation, various types of energy-efficient technologies as well as local energy supply system. The importance of embodied impacts is acknowledged in the recently published *Communication on Resource Efficiency Opportunities in the Building Sector* by the European Commission [2], aimed at promoting a more efficient use of resources consumed by new and renovated buildings and reducing their overall life cycle environmental impacts ("embodied energy" and "embodied environmental impacts" are part of the core list of indicators). This places an additional pressure upon stakeholders to go beyond a narrow focus on operational impacts in buildings.

The growing emphasis on life cycle thinking in the building and construction industry worldwide naturally leads to explicit consideration of the embodied impacts as part of such an analysis [3]. In building sustainability assessment [4], recent standardization activities now consider embodied impacts in both the European CEN TC 350 group (e.g. EN 15978 [5]), and internationally within ISO TC 59 /SC 17 group (e.g. ISO 21929-1 [6]). Therefore, a life cycle approach to the quantification of building's overall impacts to environment is needed, starting at the product stage (embodied impacts from extraction to manufacturing) through the stages of construction, maintenance, repair and replacement to end of life stage.

In this document, the term embodied impacts specifically refers only to the primary energy consumption and the adverse effects on the climate resulting from GHG emissions that arise in the life cycle due to the production, construction, maintenance, repair, replacement and end of life of the buildings. Thus, the focus here is on the indicators "embodied energy" and "embodied GHG emissions", considering that they represent a part of life cycle assessment (LCA) and can provide the different stakeholders or actors with information to use in their decision-making. For many, especially for those without extensive LCA experience, this offers a first step into the subject of embodied impacts. The basic concept can then be extended later into other areas such as water and wastes.

Assessing and managing the embodied impacts associated with buildings unlocks additional opportunities for conserving the resources and protecting the environment through, for instance, better-informed decisions related to the design and construction of a building, as well as a more effective product and process optimization in the industry. This is a challenge and additional task for all parties in the building supply chain: investors and clients, designers, contractors, construction product manufacturers and also policy makers among others. All involved stakeholders should begin integrating embodied impacts considerations into their decision-making and shift from a vision where achieving operational energy efficiency or net-zero operational impacts is the ultimate goal to one where minimizing the overall life cycle impacts is the norm.

Thus, the various stakeholders in the building supply chain need to start managing embodied impacts as part of their responsibility towards society and environment. This paper aims to assist them in understanding their role in identifying, assessing and reducing embodied impacts. For individual stakeholder groups different opportunities for actions are analysed and related recommendations are provided.

2. Stakeholders' Primary Roles and Decision-making Contexts

By virtue of their different roles in the building and construction value chain, different stakeholders have varied or diverse concerns related to the aspect of embodied impacts. Understanding their underlying concerns and decision-making contexts will help to evaluate the possibilities and challenges of integrating this additional aspect into their decision-making. Table 1 lists the types of different stakeholders (S), their primary roles (R) and concerns, as well as their main decision-making contexts in relation to the identified primary roles.

For instance, the different roles and decision-making contexts for a designer (S3 in Table 1) might include, among others:

- when providing support to the client/owner (R8), the designer assists in terms of building requirements planning, the basic construction-related decisions and the formulation of the task (the “brief”) and requirements related to the environmental performance (S3/R8).
- when designing and assessing a building (R9), he/she selects the building products and construction methods, optimizes building elements in terms of their structural and environmental performance, develops a plan for future maintenance and repair of the building, as well as for future decommissioning of the building (ease of dismantling and recycling) (S3/R9).
- when carrying out the object documentation (R10), he/she compiles information on the type and quantity of installed materials including their environmental information (S3/R10).

Table 1: Typology of stakeholders (S), their primary roles (R) and decision-making contexts (DM) in relation to their influence on embodied impacts – selected examples (based on a survey carried out within the scope of Annex 57 project [7]).

Type of Stakeholder	Primary Roles	Decision making contexts in relation to their primary roles
Construction Product Manufacturers (S1)	Product manufacture (R1) Product recycling (R2) Product description and certification (R3)	(S1/ R1) – Continuous improvement of building products through the optimization of “in-house” (corporate) processes and a change in the procurement of their primary products and energy sources (S1/ R1) – Continuous improvement of the technical quality of products (durability, ease of maintenance, ease of deconstruction and recyclability) (S1/ R2) – Development of structures and solutions to support the recycling (implementation of effective take-back of products, e.g. a “product stewardship” model) (S1/ R3) – Provision of transparent information on their product’s performance (e.g. EPD, safety data sheet)
Contractors/ Builders (S2)	Construction management (R4) Waste management (R5) Documentation and monitoring (R6) Maintenance (R7)	(S2/ R4) – Reduction of energy consumption on the construction site (S2/ R4) – Use of construction products being produced close to the construction site to reduce the amount of transport (S2/ R4) – Selection of sources of supply of the building materials and mechanical plant (S2/ R4) – Quality management to ensure a long service life of the building and avoid defects (S2/ R5) – Waste management at the construction site (S2/ R6) – Provision of information (installed products, durability, longevity of the construction works) (S2/ R7) – Development of concepts for the life cycle related services to maintain the building

Design Professionals (S3)	Provision of support to the client/ owner (R8) Building design and assessment (R9) Object documentation (R10)	(S3/ R8) – Provision of assistance to the client in terms of the building requirements planning, the basic construction-related decisions and the formulation of the task (the "brief") (S3/ R8) – Provision of assistance to the client in the formulation of requirements related to the environmental performance (S3/ R9) – Selection of building products and construction method, as well as optimisation of building elements in terms of their structural and environmental performance through the comparison of different variants (S3/ R9) – Development of a plan for future maintenance and repair of the building (S3/R9) – Development of a plan for future decommissioning of the building (ease of dismantling and recycling) (S3/ R10) – Compilation of information on the type and quantity of installed materials including their environmental information
LCA experts and consultants (S4)	Provision of expert advice to other stakeholders (R11)	(S4/R11) – Provision of advice and assistance on matters related to the preparation of detailed LCA calculations and generation (or sourcing) of LCA data.
Procurers (S5)	Procurement of buildings and construction products (R12)	(S5/ R12) – Requirements-setting for the contract specification (S5/ R12) – Contribution to Green Public Procurement (GPP) and Sustainable Public Procurement (SPP) in terms of the formulation of requirements on the environmental performance (S5/ R12) – Definition of robust metrics and KPIs
Professional Associations/ Organisations (S6)	Provision of technical guidance (R13) Development of regulations (R14)	(S6/ R13) – Publication of information and guideline documents (S6/ R13) – Sharing/provision of data, tools and experiences or case studies (S6/ R14) – Development of rules for integrating the tasks into the scope of work and fee determination
Real Estate Appraisers/Valuation experts (S7)	Appraisal of building value (R15)	(S7/ R15) – Estimation of the "cost" of the environmental impact as part of a property valuation (S7/ R15) – Consideration of the "environmental value" of existing buildings in their valuation
Government (S8)	Law- and policy-making (R16) Funding provision (R17) GPP (as a special form of procurement) (R18)	(S8/ R16) – Development of new requirements, targets and benchmarks for embodied impacts to be integrated into national policies, regulations and/or laws related to energy and resource efficiency, and/or building performance (S8/ R17) – Development of new funding programmes incorporating considerations for embodied impacts (S8/ R18) – Inclusion of requirements on embodied impacts in Green Public Procurement (GPP) and Sustainable Public Procurement (SPP)

Scientists (S9)	Development of methods and benchmarks (R19)	(S9/R19) – advancement of the methods of LCA (S9/R19) – prognosis of changes in data due to technical progress (S9/R19) – development of benchmarks through the working out of case studies
Tool/ database developers/ providers (S10)	Data and tool provision (R20)	(S10/ R20) – Collection of data in the database, evaluation of their quality and update of older data (S10/ R20) – Provision of average values to be used at the early design stages

In the following section, the key challenges for selected groups of stakeholders are discussed further, and recommendations are given to aid their decision-making.

3. Challenges and Recommendations for Selected Groups of Stakeholders

The focus of this section is to discuss the issues/challenges faced in practice specifically by construction product manufacturers, design professionals, professional associations, policy makers and experts/scientists. In addition, recommendations are provided with the aim to change the ways in which these selected stakeholders think and work.

3.1 Challenges and Recommendations for Construction Product Manufacturers

Manufacturers are increasingly integrating issues concerning the resource use and the adverse effects on the environment into their decisions on product development and optimization. This leads also to a stronger competitive position, better profit prospects and an enhanced image for their enterprise.

LCA is an instrument that can help manufacturers in this direction. Specifically, it can be used for identifying whether possibilities for improvement exist in their manufacturing and corporate processes, including their supply chain and recycling of the product. Manufacturers can contribute to the reduction of embodied impacts by means of process optimization, better procurement, improved technical characteristics and product information and take-back guarantees. At the same time, they can make data available for other stakeholders in the form of an EPD. This is also a way for them to fulfill their product responsibility as manufacturers. For the preparation and publication of EPDs it is recommended for each module (see Figure 1) to indicate individual data/information for different scenarios – e.g. individual data for different possibilities/options of the installation (A5) or recycling (D).

Furthermore, considering the 2020 net-zero energy goals in Europe, there is a “pent-up” demand for building services, photovoltaic systems (PV), and other energy-efficient technologies, leading also to a greater demand on environmental information (or EPDs) on these technologies. There is also a need for publishing more “system–EPDs”, thus environmental information for whole building systems (not only for materials), such as ETICS (External Thermal Insulation Composite Systems), drywall systems, HVAC systems, etc. Since there is a lack of such data, in many cases designers are required to combine EPDs from different materials used in the manufacturing of these complex systems, leading to loss of important information.

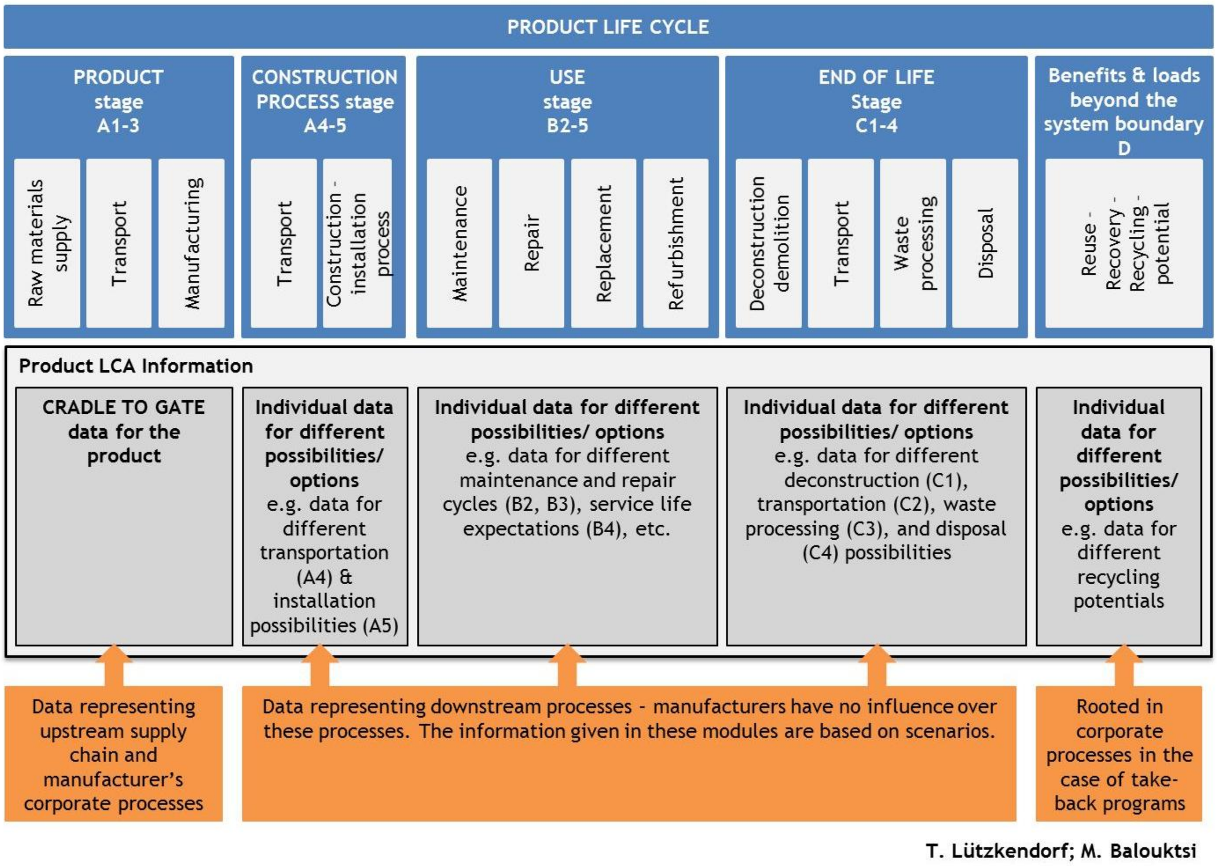

Fig. 1 An example of how product LCA information can be presented and reported following the modular approach in EN 15804 [8].

3.2 Challenges and recommendations for Design Professionals

One of the designer's responsibilities is to provide appropriate advice and technical support to the client, who might be the developer, the owner or even the public authorities (S3/R8 in Table 1). In this role, he/she should help the client to establish the goals or set of requirements for the limitation of embodied impacts as part of the sustainability related requirements in addition to the traditional requirements for technical, functional or design quality (i.e. target setting, compliance with standards, sustainability assessment, etc.). This can be achieved either via a discussion or checklist for the setting of project-specific targets, which can be either more quantitative (e.g. to abide by a "budget" for the maximum level of embodied impacts similar to the concept of cost budget), or more qualitative (e.g. to prefer the use of bio-based or recyclable materials – if available and appropriate), for the reduction of embodied impacts.

Designers should start with the assessment of embodied impacts early in the design process (S3/R9 in Table 1). It is necessary to develop an effective design strategy for achieving reductions in embodied impacts or in the life cycle related energy and mass flows and impacts to environment (trade off/optimization between embodied impacts and operational impacts) from the earliest design stages, as the opportunities for influence decrease during the design development process and the cost of changes becomes potentially higher. The assessment process of embodied impacts has a lot in common with the cost planning process. In the same manner as cost estimates, an embodied impacts assessment should start off with a target, which is usually estimated at an early stage and assessed and refined as the design evolves. However, in the early design phase the available information is often not sufficient for making a detailed assessment of embodied impacts, thus, average values for embodied energy consumption and embodied GHG emissions can be used. A transition from average data in the early design stages to product-specific data according to tendering and contracting requirements is a challenge. Another current challenge is the identification and selection of appropriate databases (when EPD data are not available; i.e. a public LCI/LCA database that is relevant locally) and tools that can be used at different stages of the design process for aggregating the data and performing LCAs. It is recommended that designers use modern tools that can improve the accuracy and efficiency of the assessment of the different design variants, while also facilitating the comparisons to find the optimum solution.

After the completion of the building information, on the type, quality and quantity of installed materials including their environmental information are compiled by designers into a final object documentation (building file) (S3/R10 in Table 1). The list included in this document of the different construction products and materials present in the building (can be a form of building file or passport or logbook) is an important piece of information to those stakeholders involved in the in-use stage of the building (e.g. facility managers dealing with the maintenance), as well as in its end-of life stage. Nowadays, it is important for designers to apply an enhanced object documentation covering also the recycling potential of the different construction materials in preparation for a future “urban mining” (i.e. where the built environment is seen as a source of materials for use/re-use).

3.3 Challenges and Recommendations for Professional Associations

Professional associations and organisations have a key duty to play in ensuring that their members are prepared and informed on the importance of embodied impacts in buildings and their products (S6/R13 in Table 1). Such efforts go a long way in providing useful information to building-industry stakeholders through, for instance, the publication of various guidelines providing essential technical guidance on the identification, calculation and reduction of such impacts [9,10, 11]. However, the various information found in the different existing guideline documents cannot fit together as one system, since they are based on different definitions, system boundaries and data sources, and thus, problems with the information flow along the supply chain arise [7].

It is a great challenge for professional associations to develop a sufficient knowledge base to keep pace with current industry-related demands. For example, in the case of designers there is a demand for average values and benchmarks to support the really early stages of the design and decision-making process, when the quantities of materials are still not known. What design professional associations could do in this case is to develop databases providing free and publicly available information to their members on completed projects (of different building typologies) with the aim to give an idea, among others, of how the embodied impacts of a new design will compare to a typical building of the same typology and structural system, and thus facilitating the benchmarking of designs. Such a database has been recently launched in the United Kingdom, for example, by the Waste Reduction Action Program (WRAP) [12].

In many cases, professional associations are responsible for developing rules related to the scope of services that should be offered by their members and the determination of appropriate fees for these services (S6/R14 in Table 1). Therefore, by integrating the task of the assessment of embodied impacts into these rules of practice (as an addition to the scope of services and an update of the fees incurred) they can contribute to the increase in the number of the professionals providing such services.

3.4 Challenges and Recommendations for Government

Federal, state and local governments being the main law- and policy-makers have a crucial role in promoting and ensuring the consideration of embodied impacts in the built environment. This can be achieved by integrating requirements, targets and benchmarks for embodied impacts into the current national or regional policies and laws related to energy and resource efficiency (S8/R16 in Table 1). In most countries, present legislation and building regulations do not address embodied energy and embodied GHG emissions based on a survey realized by the ST4 group of Annex 57 [13]. One exception is the Netherlands, where there is now a mandatory calculation of material impacts in the case of residential and office developments, although there are still no standards set. At the same time, plans to include the measurement of embodied energy and embodied GHG emissions in Building Regulations are currently under development in Austria and the UK. For example, the next iterations of the UK Building Regulations will require the inclusion of “embodied carbon” as an allowable solution within the definition of 2016 Zero Carbon Building [14]. However, without an integral approach from the government’s side translated into clear and mandatory performance requirements, the recent interest and drive towards the consideration of these aspects within the building sector will falter. In this sense, it is recommended, for example in case of Europe, an embodied energy requirement and target to be included in the Energy Performance of Buildings Directive (EPBD) and subsequent recasts, which have focused on operational impacts so far.

3.5 Challenges and Recommendations for Scientists, Experts and Tool Developers

Scientists and experts play a leading role in the further development of LCA methodologies and benchmarks through their research activities and application of their knowledge into case studies (S4/R11, S9/R19 and S10/R20 in Table 1). LCA is an evolving science based on assumptions and extrapolations from work of scientists and experts in many fields [15]. Two of the most commonly known problems in LCA are the lack of spatial and temporal considerations [16]. Thus, it is recommended the development of solutions of how to deal with the place and time dependency in LCA and how to deal, for instance, with far-off scenarios for processes such as dismantling and disposal. In addition, scientist should also find solutions to tackle difficulties and uncertainties with regard to the consideration and handling of the recycling, reuse and recovery potential (so-called module D in CEN TC 350 and ISO TC 59 SC 17 standards) in building LCA and how to treat the allocation procedure. Another important challenge for the science is to deal with the influence of the technical progress and the future changes that may occur in the electricity mix of a country (either due to an increase in renewable energy or an increase in coal-fired power plants to replace the nuclear power plants) on the primary energy and emissions factors. The investigation of such assumptions is critical, since, for instance, the manufacturing of the building components that may replace the components that has failed takes place in future. Thus, it is necessary for the specialists to find solutions to the methodological issues concerning the future changes in the energy mix and product development and to assess the sensitivity of results to different assumptions applied to the model.

4. Conclusion and Future Outlook

Considering the overall impact of the building and construction sector on the draw on our natural resources and on global environment, the explicit consideration of embodied impacts as part of a life cycle approach in all the activities in the sector is very important. However, because of the myriad roles of different stakeholders in the supply and value chains, their concerns and decisions have also been demonstrated to be varied and diverse. To enable and support them to manage embodied impacts decisions as part of their responsibility towards society and environment, these different roles and decision-making contexts were discussed, and some guidance on how different stakeholders can contribute to reducing the overall embodied impacts in the sector has been provided. Specific opportunities for selected stakeholder groups have been identified. Perhaps more important is the role of government as the main law- and policy-maker in promoting and ensuring the consideration of embodied impacts in the sector. The integration of clear and mandatory requirements and targets for embodied impacts into the current national or regional policies and laws related to energy and resource efficiency (not currently the case in most countries) can provide an important stimulus to action in the industry.

For future research, it will also be useful to map the information or data flows for these stakeholders and decision-makers, identifying the type and nature of information from one to another, as shown in Figure 2, and what type of tools are required to aid decision-making.

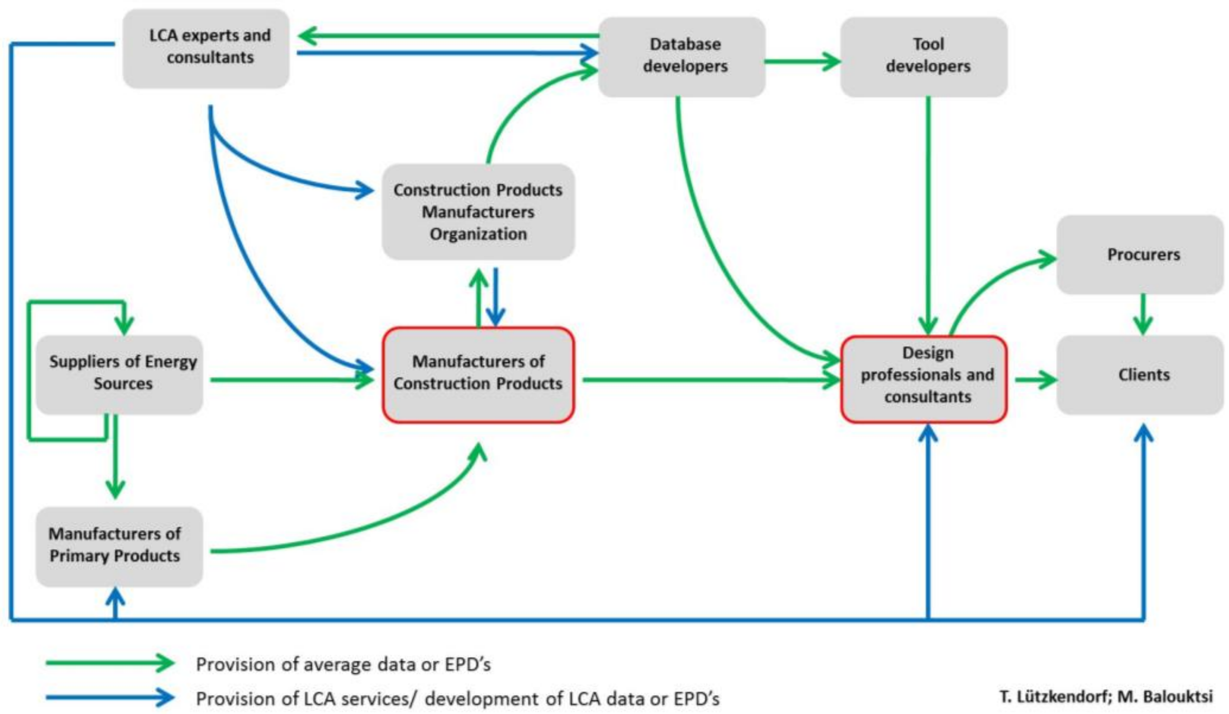

Fig. 2 Flow of LCA information or services between key stakeholders and decision-makers

Finally, the work program and expected outputs and publications from the ongoing project of the International Energy Agency (IEA) Annex 57 will hopefully provide a solid starting point for all stakeholders across the world to build on. And the time when minimizing the overall life cycle impacts is the norm will hopefully come sooner rather than later.

5. Acknowledgements

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Emerging Envelopes: Design Education for adaptive and sustainable Facades.

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Summary

Building envelopes are considered one of the main construction elements and one of the most challenging parts which contribute to the wellbeing of its users. The task is to inspire the new generation of façade planners to follow new ways of thinking and to improve the communication skills between different disciplines. This is achieved through the interdisciplinary initiative of the European Façade Network (efn) which aims to establish an academic collaboration to integrate disparate façade education, training and research across the EU.

Keywords: User needs, Building product design, Communication, Sustainability, Learning from experience

1. Introduction

Over the past twenty years, modern technologies and high functional demands have made many specializations necessary for planning-related professions in the fields of construction and architecture. As a new comer facade planning (product-related) and computational design (tool-related) are undisputedly high on the list of the most demanding and versatile specializations. Here, legal, physical, material-technological, structural-design and in particular architectural and product design together with communication skills converge. The two involved master courses - International Façade Design and Construction (IFDC) and the Master of Computational Design and Construction (M-CDC) - are part of the European Façade Network (efn) and provide an extensive overview and a scientific foundation of planning and consulting, but also enable personal specialization based on a communicational concept.

The aim of the courses is that students will acquire in-depth and skilled scientific knowledge and approaches of a technical and methodological nature related to construction and design. This knowledge is gained through different layers of communication that are used as a teaching methodology in both programs. These communication levels allow the students to understand each other both on the personal and the professional level. They open the door for better cooperation and collaboration between different disciplines, which also leads to a better understanding for the relationship between the user and the building.

A strong practical focus arises from the close cooperation with the participating companies who supply an up-to-date knowhow of the technical state of the art and new construction methods. Furthermore, external specialists and partner universities present innovative trends and current developments in research. The courses open up a future-oriented perspective, regardless of the previous qualification or professional experience of the students. Moreover, exemplary construction projects are analysed from a multitude of angles thus leading to a comprehensive overview of common problems in the future professional field of the graduates.

2. Methodology

Communication is the key factor of the teaching methodology that is used in approaching innovation and design for building envelopes. This communication concept is divided into six different levels where each level focuses on a specific topic (Fig. 1).

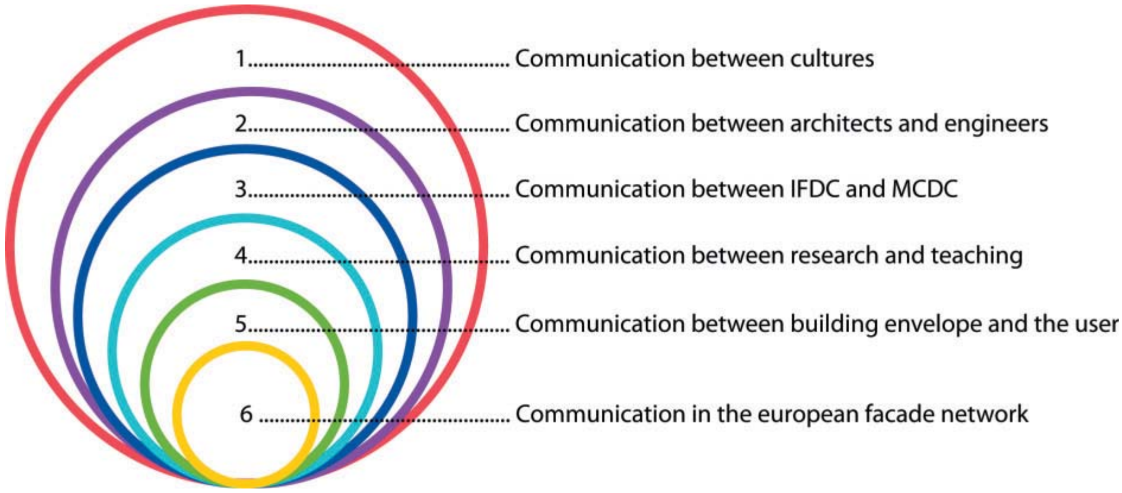

Fig. 1 Six levels of communication

These topics vary from cultural and personal communication to professional and technical communication. The first communication level starts from the basic cultural communication between the students who come from different nationalities and backgrounds. The second communication level is the communication between architects and engineers who are both admitted to master courses. The third communication level is the communication between the two master courses in joint modules. The fourth communication level is the communication between research and teaching from one side and industry and teaching from the other side. The fifth communication level is the communication between the building and the user. The sixth and the last communication level is the communication in the efn, which is represented by the cooperation between the five partner universities and some associated institutions.

2.1 Communication between cultures

Both master courses (IFDC and M-CDC) are completely taught in English in order to attract international students from all over the world. During the last 8 years students from more than 30 nationalities worldwide were enrolled in both master courses. In this international atmosphere, students get to understand and accept each other; they get to know how others work, how they behave, their attitudes, gestures and food. Students get to know the real meaning of the head movement of an Indian person, or the real meaning of "inshalla" in Arabic. From their classroom a small door is opened for the students to get to know the other sides of the world. Understanding each other in this cultural level is crucial to avoid misunderstandings and to generate openness to develop better products, buildings and facade envelopes for the future. In this diverse environment, not only the students learn from each other also the teachers may gain new intercultural competences.

2.2 Communication between architects and engineers

In both master courses, students with architectural as well as engineering background are accepted, also interior designers might be admitted to the course if they fulfil the requested inquiries and have a background related to the topic. Communication between architects and engineers has been always described as a “hot topic” in the field of construction. Therefore this challenge is tackled in an early stage of the course by challenging the students to always work in mixed teams of architects and engineers and to come out with interdisciplinary solutions for their projects and ideas.

2.3 Communication between the master courses

Knowing about the importance and the huge potential of computational methods and digital fabrication as a tool for the development of facades as a product and knowing that facades are one of the most complex building elements. The establishment of joint modules has generated an added value. There is for now at least two complete modules that the students take together and try to understand the basics of the other discipline. Beside this the students can also choose to attend other classes of the other course according to their interest and skills. This has been acknowledged very much by the students to enlarge their knowledge.

2.4 Communication between teaching, research and industry

All teaching activities are linked to the three interdisciplinary research platforms established at the partner universities of efn. At HS OWL the PerceptionLab (PL), the ConstructionLab (CL) and the UrbanLab (UL) are dealing with the built environment at different scales. The CL is primarily concerned with technological construction issues, the PL focusses on analyzing space’s qualities and impact using real and virtual environments, and the UL assembles competences and the capacities in the area of urban planning, landscape architecture, transport planning, urban water management and communication. There is a dynamic relationship between the research platforms and the master courses. Many ideas and concepts created by the students in the master courses are adapted in the research labs for testing and further development. Moreover most of the scholars are teaching in the master courses according to their competence and focus.

On the other hand there is a tight collaboration between the two master courses and industrial companies in the field of construction, materials and facades such as ABR, Schüco, Covestro and Goldbeck. The collaboration between these companies and the master courses aims to develop new ideas for individualised applications of standardised industrial products in the building envelope. It also faces the increasing challenges in distribution, technology development and production caused by the increasingly significant trend of globalisation in the market.

2.5 Communication between the user and the building

“Behind each great envelope there is a great user standing behind it.”
Before the steam engine, craftsmen used to adjust their products to individual needs, each user used to have a unique product and therefore a special relationship with it. This concept evaporated after creating the steam engine, the products became rationally produced in large quantities, cheaper price, less individual and less emotional. Nevertheless, now with the new digital technologies and the open source software development, the possibility to produce individual products as a result of mass customisation with an emotional meaning came back to life. Different from architecture and engineering disciplines product design has crossed a longer way towards interface design with the consumer.

The industrial products are closely connected with the users and their needs. According to Meyer-Eppler’s (1958) communication model (Fig. 2) the designer's task has to be to translate a product’s function into signs that the receiver can understand. Therefore product design methodologies are used in research and education in the master programs in order to develop façade concepts, elements, components and to create a meaningful relationship between the user and the building envelope based on communication and emotion. The goal is to produce products that have emotional meaning and at the same time provide functionality.

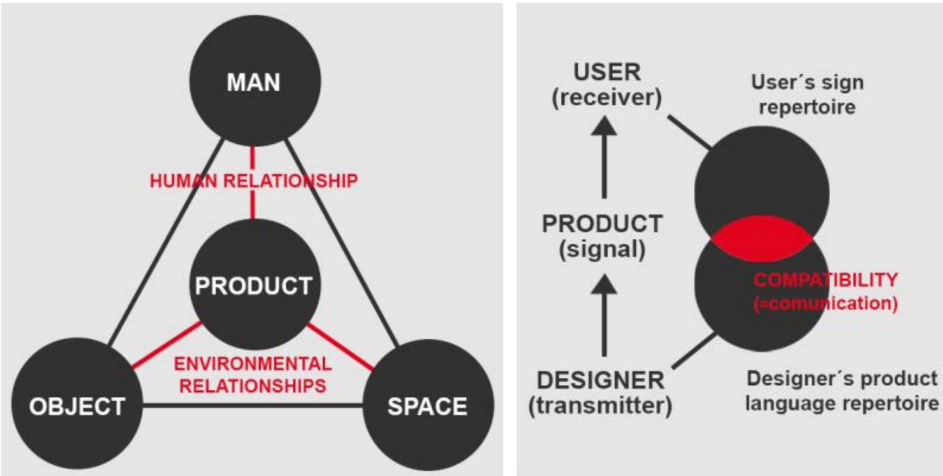

Fig. 2 Communication model according to Meyer-Eppler (1958)

Daniel Pink (2005) argues that once our basic needs are met, we tend to look for meaningful and emotionally satisfying experiences. Any design-oriented approach connects user and facade at different levels of adaptivity:

- adaptivity to movements, presence or changing comfort conditions realized by sensors,
- adaptivity to users requirements by individual regulation realized by tools, apps and programmes,
- adaptivity to functional complexity by multifunctional design by integrating interior, technical aspects into the façade.

2.6 Communication in the European Facade Network (efn)

The efn is a meeting point for science, technology and industry to exchange on facade knowledge based on results from teaching and research. It is a cooperation between five European universities which seek to advance and promote façade design and engineering at a European level and beyond. This is achieved through inclusive collaborative working between its members and alumni, resulting in skills and knowledge transfer and sharing in the following areas:

- Undergraduate & / or postgraduate façade design and engineering education,
- Conferences and workshops rotated between EFN member institutions. Supposed to send students to workshops,
- Publication through the Journal of Facade Design and Engineering (JFDE) and related peer-reviewed international journals,
- Industry informed research at Masters, Doctoral and EU level,
- Industry driven experimental façade testing.

Each semester a facade symposium that deals with current issues concerning the facade and innovation is organized in one of the efn partner universities. The symposiums are open to external participants and have established themselves as a European forum for exchange between universities, institutions, associations and industry. The symposiums take place alternately at the efn-partner universities: Ostwestfalen-Lippe, University of Applied Sciences (HS OWL), in Germany, TU Delft (TUD) in the Netherlands, Lucerne, University of Applied Sciences (LUC), in Switzerland, the University of Bath (UoB) in Great Britain and the University of the Basque Country (EHU) in Spain.

It is accompanied by seminars and workshops with international speakers and participants from the partner universities, which are - as a part of the curriculum - prepared and followed up at the course lessons. From 2014-2016 the workshops have been supported under the title of “efnMOBILE” by the Alcoa Foundation within the program “Pillars of Sustainable Education” that highlights four areas of focus: Education, Sustainable and Integrated Design; Actionable Solutions; and Community Impact. The program will assist in sharing research, applications and materials across both professional and academic channels and ultimately. efnMOBILE is taking the workshops the universities and presents the results to the facacade community as well as to the public.

3. Workshop Results

Three of these workshops and their results are presented in his paper to show how creativity, interculturality and internationality is used to create innovative application and to put theoretical knowledge into practice by applying it “hands on” to models and prototypes that are using the assigned technology.

3.1 Lucerne 2014: Interaction Design

The main topic of the workshop in Lucerne was the human-computer interaction, which is also known as interaction design, often abbreviated IxD, it is about shaping and designing digital things, tools, products, environments and services for users' needs. Interaction design has some interest in forms but the main focus of it is on behavior. Students should imagine how their new designs and products are going to create new environment and experience for the user. It is connected strongly with software engineering and programming languages and its main goal is to create a new experience for the user and satisfy their needs and desires.

The approach in the workshop was focusing on solving individual problems and needs of the users by creating emotional responses of the users. The students of IFDC and MCDC worked during the semester - and before the workshop - on developing ideas and learning technologies to build new concepts and mock ups. The students were offered a short intensive course on Firefly (plug-in for Grasshopper). It is an open source software that allows students and users to start experiencing some programming language functions and working with microcontrollers to control motors without the need to learn any programming languages. It took the students only few weeks to start playing with Arduino (a single-board microcontroller), and being able to giving some orders to the computer which controls some motors connected to the mock ups. These ideas and mock ups were the starting point for the three workshop-days in Lucerne where around 30 students from three different universities (HS OWL, Lucerne and TU Delft) and 17 nationalities met to challenge and further develop the ideas which were created at HS OWL.

One of the workshop's results was "The Movable Window" which translates the human body movement into physical movement of facade elements. This will be useful especially for persons with low mobility who want to control the amount of light in the room, privacy, view (functional aspects and communication) just with the movement of their hands. Each user can create his/her individual gesture to control the window and adapt the position and the size of the window according to their needs (individuality and communication). Controlling the movement of a heavy element from a long distance just with the movement of the hands is no longer an exclusive ability of superheroes (fun and emotional aspects and communication).

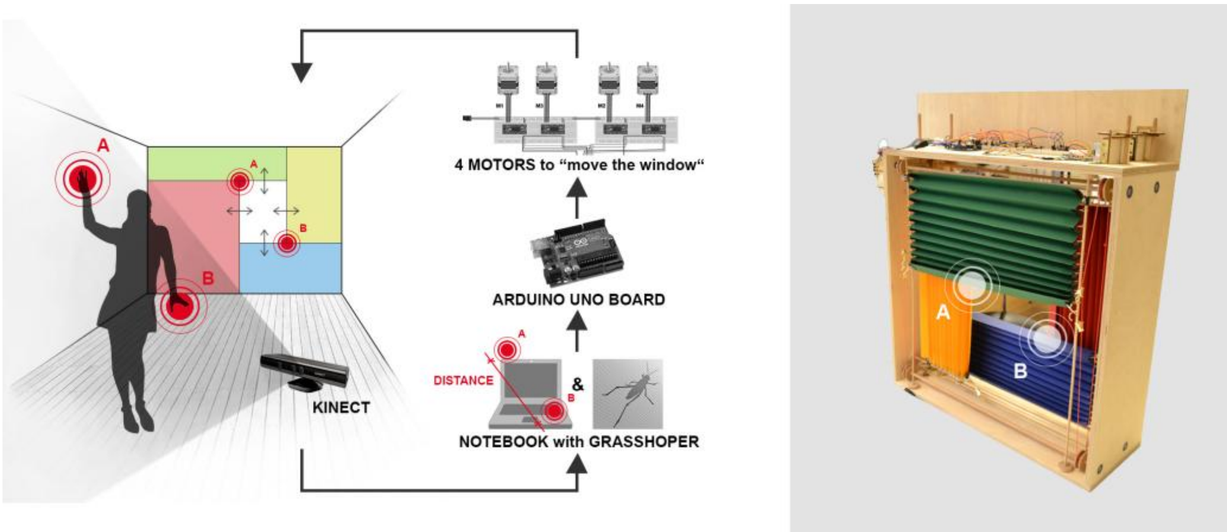

Fig. 3 The movable window by Manar Jawad and Juan Sepùlveda

Body movement is read by a Kinect Camera which is a Xbox video game tool (technology from another industry) and is translated into the digital model. The Grasshopper Firefly definition which is connected to an Arduino UNO board converts the physical movement of the hands into the physical movement of the window elements by a formula. In an interdisciplinary short workshop the students have built a very interesting physical prototype.

3.2 Delft 2015: ThinkingSkins

The workshop "ThinkingSkins" was based on the ideation of future adaptive facade concepts related to individual functions of the facade. ThinkingSkins describes the exploration of adaptive building envelopes on the basis of negotiated information. This includes the conceptual analysis of current technical developments towards a total construction system. The starting point of the student's research – already done in a prepartation phase at HS OWL - are the complex requirements of a façade. Based on a matrix these requirements are selected and became the starting point of single scenarios and concepts. Strategies of parametric designing are applied to the negotiation process of responsive reactions. The goal of «ThinkingSkins» is to improve the performance of building envelopes by continuous, intelligent adaptations in accordance with their requirements.

Students from the TUD, HS OWL and Lund University in Sweden participated in the three-day workshop. During the workshop individual functions of the façade based on atomization abilities where tested. Each student assigned in a "lottery procedure" to a facade's function, in which they should develop an innovative adaptive concept for the façade. The students were asked to present their ideas in a poster and to build a physical prototype that illustrates the function and the construction of the concept.

One of the workshop results engaged in the facade function "provide acoustic insulation" (Fig 4). The focus of his concept is to protect the interior spaces from the disturbing noises of the outside environment.

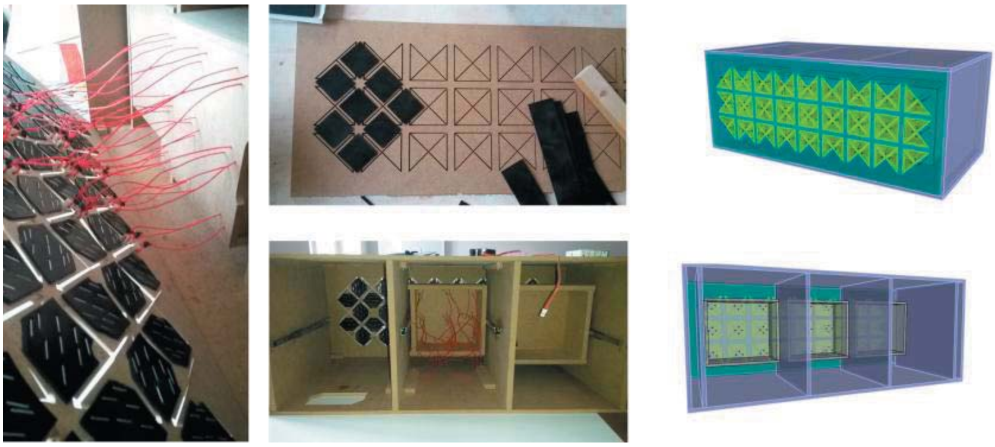

Fig. 4 The acoustic adaptive prototype by Alexander Fillies (HS OWL, M-CDC)

In the beginning different sound sources were examined to have a better understanding for acoustics behaviors. These sounds sources were categorized in different categories such as volume, duration, noise pollution and wavelength. These sound sources were then separated into two main groups: the positive and the negative sounds. The idea was to allow the positive or pleasant sounds, such as the sounds of the natural surroundings, to inter the interior space. While disturbing noises, such as the airplane noise, should be filtered. The integrated network of microphones in the prototype is supposed to receive the respective acoustic influences and accordingly to influence the envelope's reaction. Mainly three ways of envelope reaction were given: through reflection, absorption and diffusion. The prototype can react dynamically through opening and closing as a sound-absorbing layer in the facade. Managing and controlling of these reactions was solved through an Arduino-Microcontroller with appropriate programming orders.

3.3 Detmold 2015: Future City 2050

The intensive worldwide discussion about the quality of education and equal opportunities was the inspiration to organise the university conference for "Future City 2050" which was part of the Scientific Year 2015 "Zukunftsstadt" announced by the German Federal Ministry for Education and Research (BMBF). A three-day workshop at HS OWL and a two-day symposium in at Schüco

International KG in Bielefeld developed, explored and discussed scenarios, visions and concepts for educational buildings, cities and urban development in the year 2050. Five metropolis were compared: Mumbai/India (18 million), Lagos/Nigeria (10 million), Bogota/Colombia (8 million), Berlin/Germany (4 million) and the region OWL/Germany (2 million).

About 90 master students from all planning disciplines discussed the global challenges facing education, energy and sustainability, in interdisciplinary groups.. Urban planners, landscape architects, architects, interior designers and engineers worked together, looking at the technical and socio-economic aspects of school buildings as part of urban development. Five unique case studies based on existing schools in 2015 were the starting point for the new concepts. The results were presented with designs sketches for each site at the end of the Workshop.

One of the groups working on the city of Berlin chose the "integration problem" as the main challenge that they would like to solve during the workshop. Moreover they wanted to solve some other challenges such as, parents to spend more quality time with their children, increase the responsibility role of children and teenagers in the society and to expand the learning span since people should keep on learning all of their lives and not for a limited period. They suggested to use food as the core concept to approach the challenges. Food as a communication tool to improve integration in Berlin, to bring quality time for families during the meals and to improve health level in the community. This new system - called Scho-pany - is focusing on food, providing teaching and jobs opportunities for people, learning during practice, learning for longer time and spending more time together (Fig. 5).

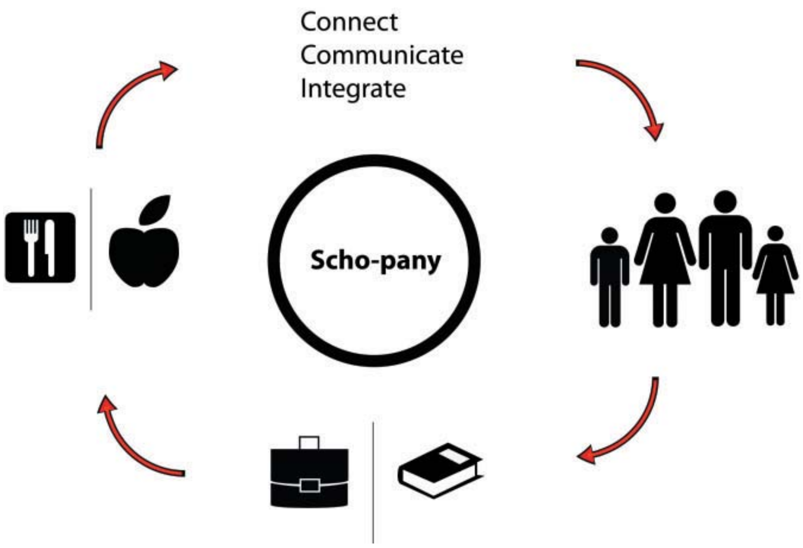

Fig. 5 Six The Scho-pany conceptual diagram by "Group Berlin 01"

The group members argued that with the current school system is not able to solve the previous mentioned global challenges. Therefore they suggested a new radical learning system where they merge a school (where children go to learn) with a company (where parents go to work), Scho-pany is specialized in growing and producing quality food that is going to be delivered to the people who are living in the same area of Scho-pany. All the subjects such as math, biology, chemistry, design and others are going to be learned through praxis in the Scho-pany. Another idea is to switch the responsibility roles between parents and children so that the children are cooking for the parents instead of the other way round.

4. Discussion

The workshops which are organised in each semester are playing a crucial role in the education concept of the international and interdisciplinary IFDC and M-CDC master courses. These workshops are not only organized to generate new ideas and practicing brainstorming, they are actually an intensive practice for the six levels of communication which have been mentioned before. Around 30-80 students, 11-17 nationalities, at least three to five disciplines from at least three different universities are usually participating in the workshops.

In order to guarantee that the students work in harmony and be productive during the tight time schedule of the workshops - which is usually three to four days - a pedagogical concept was adapted in the last workshop to foster communication within the groups, This pedagogical concept was applied in cooperation with Prof. Dr. Robin Kröger from HS-OWL (KOM), first developed and applied at TU Darmstadt. Each group of student has a “team companion” and a “professional companion” during the workshop that support the students on a personal and a technical level respectively. The role of the team companion is to observe the general performance of the group, secure the quality of communication within the group, a feedback from the team companion is provided to assure that all group members are participating in the process and that the group is moving ahead according to the time schedule. On the other hand the professional companions, who are usually lecturers and researchers of the efn partner universities or professional employees of our industry partners, are providing a minimal technical support for the team if needed (Fig. 6).

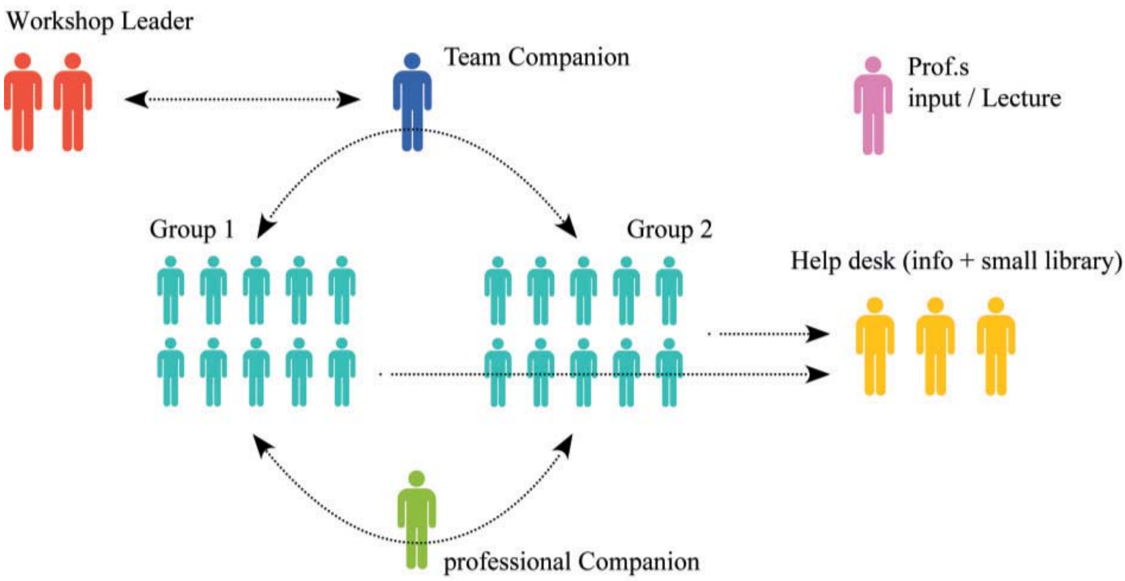

Fig. 6 Pedagogical concept to foster communication by Institut für Kompetenzentwicklung (KOM)

The communication level between the user and the building is a central part of the master courses since the façade is seen as a means to an end to improve user needs and user comfort. Therefore a longer time span is dedicated to that aspect in order to assure that the students could absorb and understand this concept. IFDC as well as M-CDC students prepare concepts and mock ups before the workshop and use them as starting point for the workshop. Together with the students from the universities these ideas are challenged and further developed during the workshops.

Professionals in product design development and presentations are usually invited to help the students to develop and to communicate their ideas. The focus is on how to develop a conceptual idea for a product and what to or not to present to the audience. Besides this presentation templates for posters, slides and physical models are provided to the students support them in communicating their ideas and results.

5. Conclusion

The experience of the final workshop in Detmold showed that it is possible to organise, motivate and guide larger and inhomogenous groups through – especially by improving communication in general but also specific communication skills within the groups. The students highly acknowledged this support and limited guidance. They also appreciated the opportunity to present the results in a larger public and professional context as a sign of respect for their work. Altogether the workshop conception helped to increase maturity and responsibility of the participants in general and for the improvement of design in the field of facade technology towards a human- and user-centered approach.

6. Acknowledgements

The authors want to thank Alcoa Foundation for supporting this series of workshops to improve interdisciplinary and sustainable models of communication and construction. We would like to thank all our university partners that helped to make the workshops happen by providing space and permissions. Finally our gratitude goes to all organisers and lecturers such as Ethan Kerber, Jens Böke, Jens Renneke, Benjamin Dally, Oliver Glahn, Ricarda Jacobi, Marco Thies for their input. External support was given by Susanne Gosztonyi (Lund University) and Wijnand Manen (Alcoa) and Johanna Funck (Generationdesign). Last but not least a special thanks to Robin Kröger for introducing a new workshop methodology.

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Enabling energy sufficiency as a sustainable development concept in shrinking urban districts: the case of Wuppertal-Vohwinkel

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Summary

De-industrialization, climate and demographic changes are only a few key words that indicate the challenge of urban development in many industrialized countries for the coming decades. A fundamental transformation of infrastructure and the built environment is expected to adjust to future needs. Numerous concepts of integrating efficiency and renewable energy sources into urban planning were elaborated in recent years. Energy sufficiency in the meaning of voluntary demand reduction of energy intensive goods and services is the third and mostly forgotten pillar of sustainable development. However, organizational and spatial measures are needed to support behavior modification. This paper presents results of a transdisciplinary research design with local stakeholders and scientific experts to develop an understanding of what energy sufficiency might contribute to sustainable urban development. Based on the Multi-Level-Perspective of the transition research approach, it analyzes how stakeholders and experts define energy sufficiency structures for the shrinking district of Vohwinkel (Germany). The paper also shows a compilation and evaluation of measures which facilitate energy sufficient behavior in the fields of space heating and passenger transport on a local level. The methodological concept comprises expert interviews, thought experiments with stakeholders to develop a vision of an “energy sufficient Vohwinkel 2050” as well as a stakeholder workshop to discuss the results. A shrinking population is seen as a chance to actively adapt the built environment to foster energy sufficiency.

Keywords: energy sufficiency, sustainable urban transition, transdisciplinarity, long-term vision

1. Introduction

Urban development in many industrialized countries faces several challenges for the coming decades. Reducing greenhouse gas (GHG) emissions by 80 to 95% until 2050 compared to 1990 is one of the most demanding missions for these countries [1]. Cities are being recognized not only as key sites in the production of GHG emissions but also as especially vulnerable to the impacts of climate change (e.g. flooding, urban heat islands) [2]. Although it is not a new phenomenon, an increasing number of cities around the world will be confronted with de-industrialization, economic de-growth and a shrinking population [3]. A fundamental transformation of infrastructure and the built environment is thus expected to adjust to future needs [4]. New kinds of systems in transport, energy and industrial production will arise which entail not only new technologies but also an alteration in user practice, cultural discourses, policies and governing institutions [5].

Theoretical considerations on sustainable development strategies discuss three fields of options: *Efficiency* is a course of action with which the input-output relation is improved (BETTER). Referring to energy use, a reduced amount of energy input is needed per unit good/service. Since it is a relative and not an absolute term, energy use can remain the same when efficiency improvements are offset by a raise in demand [6]. *Consistency* aims at qualitative changes in production and consumption by resource substitution, adaptation to renewable resources and a circular economy (DIFFERENT) [7]. *Sufficiency* in the meaning of voluntary demand reduction of energy intensive goods and services is the third and mostly forgotten pillar of sustainable development strategies. Sufficiency calls into consideration the absolute level of output or consumption per se and not in relation to the input [8]. Moreover, authors have argued that sufficiency as a concept also raises the question for levels of “enough” and helps to explore the potential of making it easier to live a *good life* (LESS/ENOUGH) [9]. As of now there is no common definition of sufficiency. This paper follows a pragmatic approach proposed by LINZ [10]. It draws attention to energy saving behavior in the management, purchase and using phase of energy intensive goods and services. It also allows defining indicators to measure sufficiency and helps different stakeholders to develop concrete measures at a local level. Because of the plurality of discussion, a definition of *energy sufficient behavior* is given in this paper with suggestions to operationalize sufficiency in two urban energy using sectors which account for a great share of energy demand: passenger transport and space heating in residential buildings.

Numerous concepts of integrating efficiency and renewable energy into sustainable urban development were elaborated in recent years. However, a growing number of studies on long-term mitigation potential of renewable energy resources and energy efficiency suggest that the goal of reducing GHG emissions will not be met without adaptation of energy demand behavior [11] [12]. They state that the inclusion of *high-hanging fruits* (costly and yet to be developed technologies) in the estimation of energy efficiency and renewable energy source potentials may lead to an overestimation of the potential to reduce GHG emissions and increases uncertainties.

The main aim of this paper is to conceptionalize sufficiency as a strategy to enable sustainable urban transition based on the case study of Wuppertal-Vohwinkel. In the next chapter, the methodological approach is presented. Because little is known about the perception of local stakeholders, who represent a meso-perspective between the individual and the political sphere, a participatory research design is elaborated. Chapter 3 gives insights into the theoretical concept of the Multi-Level Perspective (MLP) to analyze and develop long term transitions. Moreover, a definition of energy sufficient behavior is given. Chapter 4 presents results of the stakeholder analysis (1), applies the MLP to the evaluation of Vohwinkel by stakeholders and experts (2) and gives an overview of measures to foster energy sufficiency in the fields of space heating and passenger transport (3). Chapter 5 discusses consequences of the findings followed by a conclusion in chapter 6 which also points out further research needs.

2. Methodology

The literature review in chapter 1 demonstrated the lack of transferring and applying the concept of sufficiency in the light of sustainable urban transition on an empirical case. There is little knowledge concerning the definition and measurement of sufficiency in local practice. That is the

reason why the following case study is based on an explorative, transdisciplinary and qualitative oriented research design.
Meeting the requirements of a transdisciplinary approach, stakeholders play a crucial role in the initial period of the research project. Several interlinked steps characterize this period: a formulation of the exact research objective was influenced by gathering background information on the reference area Vohwinkel and a literature analysis of the current state of research in sustainable urban transition and sufficiency. The selection of Vohwinkel took place in a focus group discussion as well as an on-site-inspection with representatives of the community and the local public utility company. Vohwinkel was chosen because of its predicted population loss of over 20% until 2050 and an ongoing de-industrialization. Explorative interviews with selected stakeholders, who are considered masterminds of innovative strategies for urban development by the community, were conducted to develop a first understanding of energy sufficiency on a local level and to choose fields of interest. The main phase of research process is divided into three data collection parts. First, 15 in-depth interviews with scientific experts were conduced to develop a concept of energy sufficiency as a strategy in urban sustainable transition. In an assessment phase energy sufficiency was further operationalized. Moreover, a first stakeholder analysis and a variety of measures to foster energy sufficient behavior were developed. Experts were selected due to their scientific publications in the field of urban planning as well as demand reduction in transport and space heating. Second, 15 face-to-face stakeholder interviews with thought experiments were conducted with local stakeholders to develop a long-term vision for an “energy sufficient Vohwinkel 2050”. Third, all stakeholders, who had participated in the interviews, were invited to a workshop in order to discuss the results.

3. Theoretical Considerations

The aim of this chapter is twofold: the first part explains the Multi-Level Perspective which guides the analytical part of the case study about Vohwinkel. It presents the main structure of the concept. In the second part, the understanding of sufficiency is reflected and operationalized in two urban sectors: passenger transport and space heating.

3.1 Sustainable urban transition and the Multi-Level-Perspective (MLP)

One manner to examine sustainable urban transitions lies in the socio-technical transition approach which focuses attention to processes, reasons and the management of fundamental structural transitions to a new system. In contrast to other theoretical approaches (e.g. policy cycle, complex system theory), the concept not only aims at describing and explaining transitions, but turns the attention to the management of currently ongoing transitions. One of the basic concepts of the transition research approach is the MLP. The concept provides us with a foil that helps to describe and inspect signs of future or ongoing transitions. This takes place in connection with an elaboration of courses of action and the questions of how and by which elements the development is affected [13].

According to the MLP, transitions occur due to developments on three different functional levels in which elements of these levels also interact with each other. On the level of the *socio-technical landscape* processes develop which can hardly be influenced directly by local stakeholders. This can be gradual changes in a long-term perspective like environmental changes and cultural alteration. These exogenous processes form the macro level and build up pressure for changes at the meso level [14]. The so-called *socio-technical regime* represents the meso level. Three dimensions sharp and stabilize this level: firstly, the network of main stakeholders, secondly formal, normative and cognitive habits and thirdly material and technical elements [15]. A socio-technical transition is characterized by a fundamental change in all dimensions until a stable regime leads to a new configuration of stakeholders, commonly agreed attitudes, rules and infrastructures. The *socio-technical niche* is located at the micro level where innovation and new structural configurations develop.

The aim of the case study is to shed light on aspects of the actual situation and ongoing developments in Vohwinkel that might form the basis for a sustainable urban transition. The concept also helps to generate an idea of how a sustainable Vohwinkel might evolve against the background of energy sufficient behavior.

3.2 Definition and Operationalization

This paragraph illustrates how energy sufficiency can be defined in the context of this study and how it can be operationalized. The pragmatic understanding of sufficiency in accordance with LINZ [10], which is primarily based on resource saving behavior in the management, purchase and using phase of goods and services, gives a starting point. It indicates that sufficiency is not restricted to the consumer behavior at an individual level which is expressed by an abandonment of certain accomplishments or modesty. The definition rather comprises all parts of economic, political and societal life which opens the view to aspects of urban development. More concretely, sufficiency deals hereinafter with the establishment of behavior which results in an absolute demand reduction of energy intensive goods and services. The emphasis on energy refers to the goal of GHG reduction of sustainable development. To put it in a nutshell, the understanding of sufficiency is not solely attached to the normative debate concerning behavioral disposition on an individual level but draws attention to structural conditions for alteration of behavior in a certain regional context. Energy sufficiency is expressed by a reduction of heating demand of households as well as avoidance of motorized passenger transport caused by behavior modification.

In the field of space heating, two approaches enable energy sufficient behavior:
- Reduction of the average room temperature measured in degree Celsius
- Reduction of heated floor space per person measured in square meter

In the field of passenger transport, two approaches can be distinguished as well:
- Reduction of trip length with motorized vehicles per person measured in kilometer
- Reduction of trip number with motorized vehicles per person

In both fields energy sufficient behavior can be examined on two levels of decision making which represent starting points for organizational and spatial measures. One starting point deals with decisions during the purchase, rental and investment phase (e.g. apartments, cars). These, only periodically made, decisions often determine energy use for a long period of time. Another starting point to influence energy sufficiency is looking at decisions during the using phase of building and transport infrastructure (e.g. choice of room temperature, choice of trip length and frequency). Daily changes are possible; however, routines might hamper adaptation.

To further specify sufficiency in practice, SACHS [16] generated the concept of the four E's (Entrümpeln, Entschleunigen, Entkommerzialisieren, Entflechten) which can be translated as the four Ds: downsizing, disentanglement, deceleration and de-commercialization. The four Ds serve as guidelines to analyze policies and practical actions for sufficiency.

Mirroring the theoretical considerations, *energy sufficient behavior* is defined in the context of this study as: *an absolute demand reduction of energy intensive services per person due to behavioral changes during the purchase, rental or investing phase as well as the utilization phase of goods and services.*

4. Results

The following chapter gives a compact overview of the stakeholder analysis and the vision of “an energy sufficient Vohwinkel 2050” by stakeholders. It analyzes how they rate their own role as well as the fields of action on the ground. Scientific experts complete the evaluation of framework conditions on the landscape level and help to identify the stakeholders.

Based on the expert interviews, seven key stakeholder groups were identified. Table 1 illustrates these groups by giving further details of particular members.

Table 1: Important stakeholders for fostering energy sufficiency on a local level

Key stakeholder groups	Members
municipality	city planning department, local politicians (members of the city parliament, district representatives)
citizens	residents, consumers, users of infrastructure
non-governmental organizations (NGOs)	associations and clubs, religious communities, church organisations
local economy	traders, retailing, craftspeople, architects, energy consultants
real estate market	house owners, housing association, house owner associations, tenants associations
transport companies	public transport suppliers, car-sharing suppliers
locally known personalities	e.g. former mayors, presidents of sports clubs

For about one half of the interviewees in Vohwinkel energy sufficiency is an unknown concept concerning sustainable urban development. The other half is well aware of energy sufficiency and claims that they try to integrate it in organizational and planning processes for quite a while. Especially non-governmental organizations, representatives of the municipality and transport companies are already keen on enabling the concept. However, they all express the wish to be able to be more involved in this direction. Structural and personal constrains (e.g. unwillingness of supervisors to engage in the topic) make it difficult for them. All interviewed stakeholders can imagine making an essential contribution to foster energy sufficiency in the future. Concerning their own role they see themselves as vision multipliers and guides due to their personal energy sufficient behavior. Moreover, they envision themselves as main actors providing awareness training and consulting services to transfer energy sufficiency in different aspects of everyday life. Another field of action which was particularly mentioned by the municipality (politicians and city planning) was setting an organizational and spatial framework to foster energy sufficiency.

The MLP concept provides a basis for the structured analysis of the current district development in Vohwinkel with respective framework conditions and future development potentials. According to the interviewees, the current regime is shaped by a variety of cultural, economical and infrastructural conditions that determine an unsustainable lifestyle and economy. These elements comprise a car-oriented transport and spatial planning culture in the city of Wuppertal, a continuous increase of living space per person and in absolute terms, an exacting demand of comfort and individualistic lifestyles as well as a disperse distribution of the shrinking population in the district. On the landscape level, several factors are identified which exert pressure for changing the system on the regime level. Experts and stakeholders mention a beginning re-evaluation of values to a non-materialistic way of living by social groups. Moreover, they mention the recognition of climate change, a global financial crisis and increasing energy prices on the long run. Next to these external factors which can be hardly influenced by the local level, interviewees point out several factors which put the current way of living in Vohwinkel under pressure. These are a population decline in Vohwinkel, closing of social infrastructure and public bus routes, a fall in value of real-estate and an aging population with changing demands on the built development.

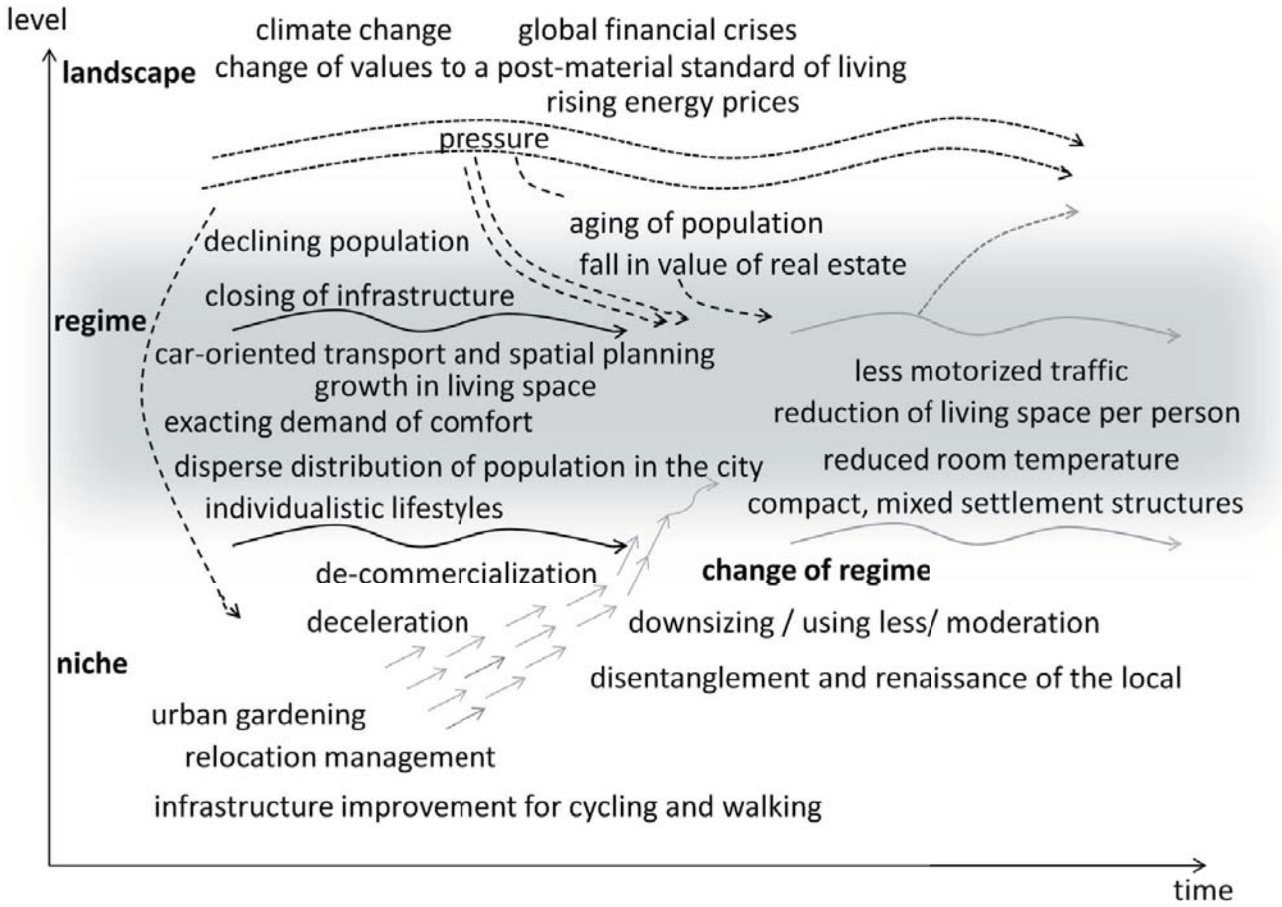

Figure 1: The MLP concept applied to Vohwinkel (own illustration based on GEELS [17])

The assessment also reveals the existence of several points on the niche level which can be seen as levers to fundamentally change the regime. These include on the one hand a broad stakeholder constellation, which can imagine supporting energy sufficiency in the future. On the other hand, stakeholders identified innovative measures to support a change in behavior. What those instruments might be and what effects they develop is shown in table 2 and 3 for the fields of space heating and passenger transport.

If new behavior patterns and infrastructural changes prevail, this will lead to a fundamental transition of the current way of living in Vohwinkel expressed by a decreasing demand of energy intensive goods and services. The new regime is defined by a demand reduction of motorized transport, less heated living space per person, a decreased room temperature as well as a compact and mixed settlement structures in Vohwinkel. The consulted stakeholders could well imagine that a variety of the proposed measures will be put into practice in Vohwinkel. However, they pointed out that a re-evaluation of current lifestyle choices is a prerequisite.

Table 2: Strategies and measures to foster energy sufficiency in the field of space heating

Goal	Strategy	Measures	4 Ds	Frequency of decision	Elements of change
more inhabitants per household	shared apartments, cross generational housing projects	information campaign, modification, new building	downsizing, using less and flexible use	periodically	organizational arrangements, urban structure, single building, information basis
less heated floor space per household	relocation when household size changes	relocation management, accommodation exchange	downsizing, using less	periodically	organizational arrangements, urban structure,
	variable floor plans	modification, new building	downsizing, flexible use	periodically	organizational arrangements, single building, information basis
	splitting large houses	modification, information campaign	downsizing, flexible use	periodically	organizational arrangements, single building, information basis
	smaller Ø apartment size for new buildings	new building	downsizing, moderation	periodically	single building, information basis
	common rooms in apartment buildings (laundry, workshop)	information campaign, modification, new building	downsizing, de-commercialization	periodically	organizational arrangements
conscious heating and ventilation habits	distinction between day and night time in room temperature	information campaign, education, neighborly competition, technical assistance systems	downsizing, moderation	daily	organizational arrangements, information basis
	user specific selection of room temperature (living room, bedroom)	information campaign, education, neighborly competition, technical assistance systems	downsizing, moderation	daily	organizational arrangements, information basis
	shock ventilation	information campaign, education, neighborly competition	downsizing, moderation	daily	organizational arrangements, information basis

Table 3: Strategies and measures to foster energy sufficiency in the field of passenger transport

Strategy	Measures	4 Ds	Frequency of decision	Elements of change
maintaining of neighborhood supply	multi-purpose shops; pick up point for internet orders	disentanglement, renaissance of the local	daily	organizational arrangements
	decentralized kindergarten and schools	disentanglement, renaissance of the local	periodically	organizational arrangements
avoidance of mono-structured zones and preservation of local activity options	support of local clubs and civic engagement; youth center, sports facilities, urban gardening, attractive meeting sites, playgrounds	disentanglement, renaissance of the local; de-commercialization	daily	organizational arrangements, single building, information basis
	home office ; enabling of e-commerce and e-banking	disentanglement, renaissance of the local	periodically	organizational arrangements, information basis
	support of trip chains due to strategic location planning	disentanglement, downsizing	periodically	urban structure, single building
compact urban forms	shrinkage form the edges – contraction, demolition	downsizing, moderation	periodically	organizational arrangements, urban structure, single building
	relocation management, accommodation exchange	disentanglement, downsizing	daily	urban structure, information basis
improvement of non-motorized transport; reduction of motorized transport	enhancement of conditions for walking and cycling, increasing spatial resistance e.g. traffic calmed area /30 km/h area, parking space control: higher tariffs, less spaces	deceleration	daily	organizational arrangements, Urban structure
consulting services; campaigns to foster energy sufficient transport behavior	mobility management, competitions to save energy with transport component, car-free Sundays, highlighting energy sufficiency as children and age appropriate	deceleration, renaissance of the local	daily and periodically	information basis

The category *frequency of decisions* in table 2 and 3 relates to the frequency with which citizens reach a point to change or determine their behaviour (daily/periodically). The category *elements of change* explains which kind of modification are initiated by the respective measure. Besides architectural and spatial (infrastructural) alterations, there are also *soft* factors like organizational arrangements and a change of the information basis. The category *4 Ds* refers to the four dimensions of characterizing sufficiency measures and policies (see chapter 3.2).

5. Discussion

The analysis of strategies to foster energy sufficiency has shown that most of the actual measures are neither radical new instruments nor technical solutions for a sustainable urban development. It is rather a modification of infrastructural conditions in the district (e.g. number and location of schools, shops and residential areas). Although stakeholders expressed their interest in energy sufficiency as one possibility to enable sustainable urban development it became also evident that some processes with regard to a shrinking population make it harder to behave energy sufficiently e.g. an increasing vacancy of apartments results in lower rental fees which might motivate for a larger floor size.

One benefit of looking at the local level to develop an idea of energy sufficiency represents the municipalities' discretion to act with regard to the design of settlements and transport structures. The choice of housing locations within the city determines important sufficiency parameter such as trip length, choice of modes of transport. Most trips start or end at home. An additional asset of the local level illustrates the fact that peer groups such as neighbors and friends serve as important point of orientation for changing behavior. Social acceptance and motivation can play a crucial role in rating energy sufficiency as a guiding principal for action.

The advantage of choosing a shrinking district as a case study can be seen in the fact that a declining population results in the need for infrastructural chances with regard to transport and spatial structure. That is why measures to enable energy sufficiency can contribute to an enhancement of otherwise challenged districts. In principle, most European cities bring a good basis for energy sufficiency oriented lifestyles due to the high concentration of buildings and people. However, a declining population and a lack of financial resources of municipalities might also challenge the realization of energy sufficient structures.

6. Conclusion

Finally, it should be stress that the municipal level emerges as a suitable starting point to enable energy sufficiency according to the case study. Stakeholders express their motivation to engage themselves more actively with energy sufficiency in combination with fostering energy efficiency and renewable energy sources at the urban level.

The Multi-Level-Perspective constitutes a valuable scheme to analyze the ongoing developments and to envision future pathways. However, a long-term vision of an energy sufficient Vohwinkel is straightforward and some measures are seen as desirable but not very likely to be implemented under current conditions. The paper gives a first idea for starting points to transform the fields of space heating and passenger transport to more energy sufficient systems. The continuing participation of stakeholders during the whole research process ensures an interaction with the concept and increases support for the idea of energy sufficiency.

There is a need for further research concerning implementation opportunities of the concept in practical application. The development of quantitative scenarios estimating the effects on sustainable development goals such as GHG reduction potentials might enhance the discussion of energy sufficiency on the ground. Furthermore, the development and implementation of real-world laboratories can further reveal chances and problems of energy sufficiency.

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Energy-plus primary school Hohen Neuendorf: Measurement based evaluation of a hybrid ventilation system

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Summary

The energy-plus primary school Hohen Neuendorf (GSHN) is characterised by an innovative, hybrid ventilation concept; it combines natural (free) pulse ventilation with basic mechanical ventilation.

After two years of intensive monitoring, research has shown that this particular type of ventilation system provides a consistent high quality of air for indoor use, whilst minimizing energy consumption.

However, this concept also requires that there is a continuous error-free operation in order for it to work effectively. Under normal conditions the operation and user acceptance as well as efficiency of the system can be improved by a more controlled strategy of user handling and system operation.

Keywords: monitoring, hybrid ventilation, air quality, energy-plus, energy efficiency

1. Introduction

The primary school Niederheide in Hohen Neuendorf (GSHN) was designed and built around an energy-plus concept and was funded by the German Ministry for Economic Affairs (BMWi) as part of the research program ‘Energy Optimised Building’ (EnOB). This involves intensive monitoring over two years, conducted by the Hochschule für Technik und Wirtschaft Berlin.

The energy concept of the building is characterised by an innovative, hybrid ventilation system which combines natural (free) pulse ventilation with basic mechanical ventilation. The mechanical ventilation injects supply air into the teaching areas. Subsequently the air streams through the corridor area into cloak and sanitary rooms where exhaust air is absorbed. By default, a low air volume flow rate fulfils hygienic requirements of sanitary rooms, while a second, higher ventilation level for extreme weather situations is available. Heat recovery is achieved with a central air handling unit. A natural (free) pulse ventilation overlies basic ventilation (see fig. 1). Determined by the air temperature outside, vertical, motorised airing panels open automatically during break times, facilitating regular airing of the room. Another pre-ventilation event occurs before occupation is resumed, in order to exhaust volatile organic compounds (VOC) and welcome pupils with fresh air. In standard operation the mechanical ventilation runs a nominal air change rate of 1 ACH, while natural pulse ventilation is designed to achieve an exchange of the entire air in the room in one sequence. If desired, additional windows can be opened manually.

Furthermore, this concept allows for natural ventilation at night and avoids overheating of the building in summertime by using its thermal mass for passive cooling. The system is designed to concurrently achieve good air quality, thermal comfort conditions and low energy consumption.

As part of the building monitoring, two model classrooms were subjected to intensive measuring. This included air conditions inside and outside (CO_2 concentration, temperature and humidity), heating and electricity demands as well as data transfer from the building services (e.g. opening status and presence).

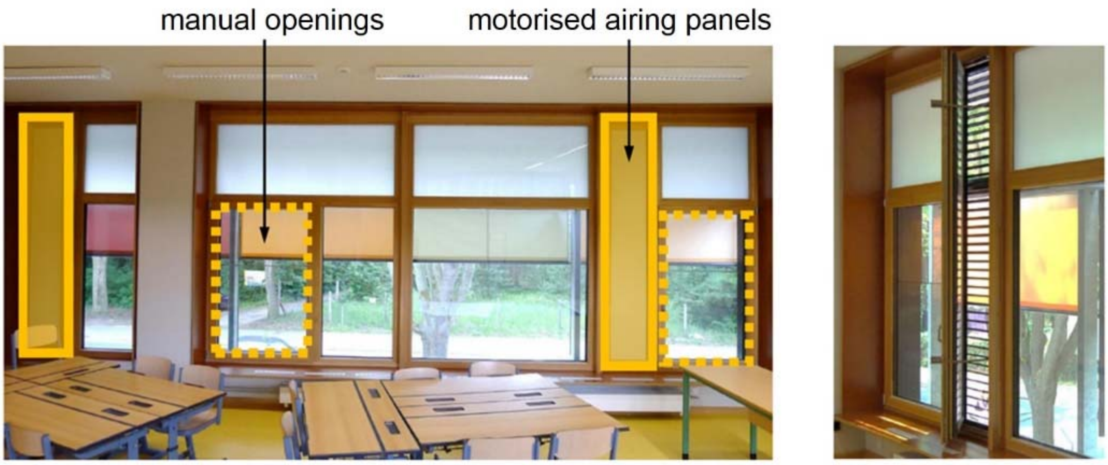

Fig. 1 Motorised airing panels and manual openings for natural (free) ventilation of class rooms [1].

2. Commissioning and fault detection

A measurement based evaluation requires an error-free operation of the hybrid ventilation system. In this context, the motorised airing panels present an unexpected challenge. Multiple partners are involved in constructing such an apparently simple system (architects, expert planners, window fitters, electricians, control engineers, engine manufacturers, etc.), thus fault analysis and correction can be complicated and time-consuming. In future projects, responsibilities should be clarified by a contract in advance ("fulfilment"). Possible sources for faults are:

- tight or defect hinges
- overloaded power supply
- asynchronous operation of the motors
- twisted window construction
- defect anti-trap protection
- incorrect programming and malfunctions of building automation

Mechanical problems can be prevented by regular maintenance. In the GSHN, due to insufficient maintenance and corrections of faults, in many areas there was no error-free operation recorded during the entire monitoring period.

In addition, pulse ventilation was often switched off manually when outside air temperatures were low, as natural ventilation allows external, unconditioned air into the building resulting in thermal discomfort - particularly in cases of failure. But even regular operation practice shows that fixed settings for the opening periods are not suited for all user-situations. Because it requires a trained technician to implement changes to the system, they are in practice rarely made due to the expense. Adjustments by the user (or an authorised person) are impossible, but may increase the acceptance of the hybrid ventilations system significantly. At the very least, in future projects an outside air temperature below which natural ventilation is disabled (in extreme weather situations) and opening periods, should be settable for each zone.

3. Operating behaviour

3.1 Electricity consumption

In regular operation, room for improvement in further building projects is apparent. The motorised airing panels expend about 12% of the total electricity consumption for ventilation. This is very small in comparison to mechanical ventilation, but more savings are possible: the three airing panels of one classroom collectively consume 8 W in standby mode. Short peak loads of about 30 W for the opening and closing processes generate an insignificant consumption of less than 5% of total consumption (see table 1). A consistent motor control cut-off outside operation periods could significantly reduce the total base load of the building.

Table 1: Operating hours, electricity consumption and stand-by ratio for motorised airing panels in the two model classrooms.

Room	Classroom 2.2		Classroom 4.2	
School year	2012/13	2013/14	2012/13	2013/14
Operating hours[1)]	8741 h	8759 h	8741 h	4638 h
Electricity consumption	70 kWh	71 kWh	70 kWh	37 kWh
Stand-by ratio	96.2%	97.2%	95.7%	97.4%

1): Operating hours of motor control unit. Downtimes caused by mechanical defects are not included.

3.2 Weathering protection

To avoid water ingress in the event of driving rain natural ventilation is disabled by the building’s automation system. The algorithm evaluates rain status as simply ‘yes’ or ‘no’. Thus, in situations of low rainfall and low wind velocity, sufficient fresh air is not provided by natural ventilation. This not only leads to increased CO_2 concentrations during school times, but also prevents effective cooling at night. A more intelligent evaluation of the weather conditions, involving precipitation rate and/or wind velocity, would decrease weather related downtimes significantly and improve the efficiency of the natural ventilation system.

The example in figure 2 illustrates that even short periods of precipitation can affect the ventilation concept of GSHN considerably: brief rainfall interrupts night ventilation at 04:30 and prevents an operating sequence at 08:45. Table 2 lists the number of occupied days with less than four opening sequences, this being significantly less than the planned minimum of five opening operations (incl. pre-ventilation). This occured in 75% of total days of occupation for school year 2012/13, and only 40-46 % in 2013/14. The difference correlates with the comparative durations of rainfall in both periods. In school year 2012/13 it rained for 816 hours, in school year 2013/14 only 587 hours.

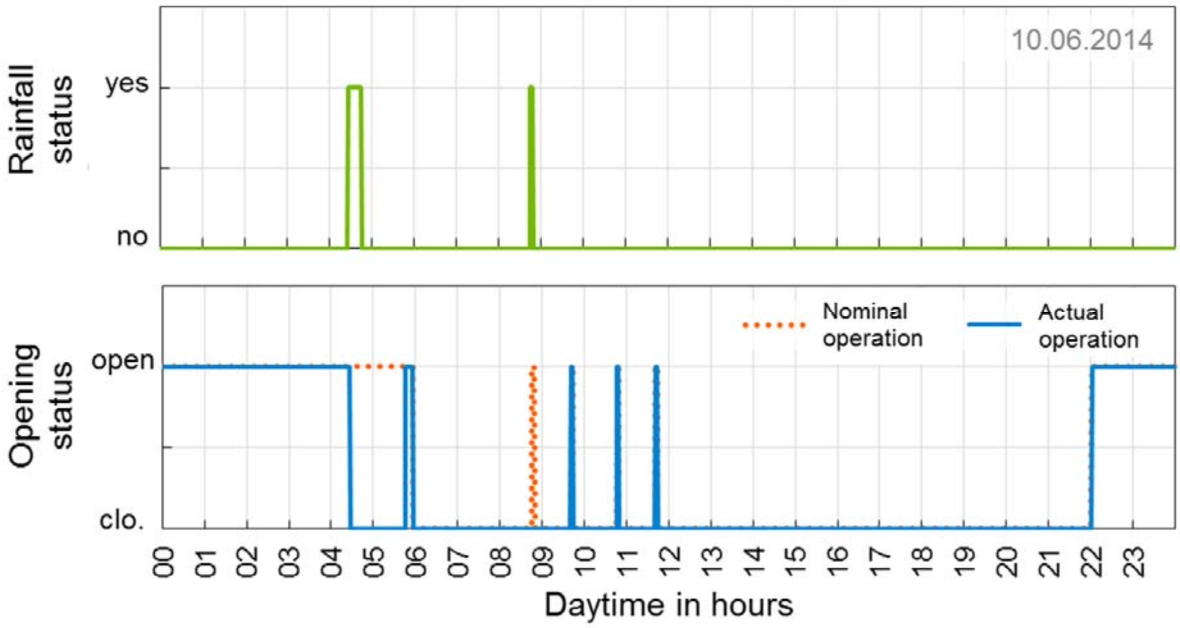

Fig. 2 Rainfall status (top) and opening status in actual and nominal operation of the airing panels for classroom 2.2 (down) on 06.10.2014.

Table 2: Number of days of occupation and number of days with less than four opening sequences for natural pulse ventilation.

Room	Classroom 2.2		Classroom 4.2	
School year	2012/13	2013/14	2012/13	2013/14
Number of days of occupation	182 d	195 d	189 d	197 d
Number of days with less than four opening sequences[1)]	136 d (75%)	89 d (46%)	141 d (75%)	80 d (40%)

1): Opening sequences of motor control unit. Downtimes caused by mechanical defects are not included.

3.3 Heating and ventilation times

Monitoring-data shows heating demand even in transitional periods and in summertime. By looking at figure 3 the reason can be deduced: it shows time series of room air temperatures, as well as times of night ventilation, pre-ventilation and heating demand on two selected dates. Following night ventilation the room is heated until target temperature is obtained; then a pre-ventilation sequence is completed before the room is heated again. The heating-process between the two ventilation periods necessitates unusual heat demand for summertime. With the aim of optimizing operation, pre-ventilation was moved to 05:30, meaning that night-ventilation and pre-ventilation were simultaneous. Obviously, the interaction of heating and hybrid ventilation system has a considerable impact on heating energy consumption and can be substantially improved. In particular, presetting a lower target temperature outside occupation times can avoid unnecessary heating processes after ventilation sequences. Furthermore, the room temperature rises after break times by internal gains and thermal mass, suggesting that implementation of a variable reaction time for the heating system may lead to less energy demand.

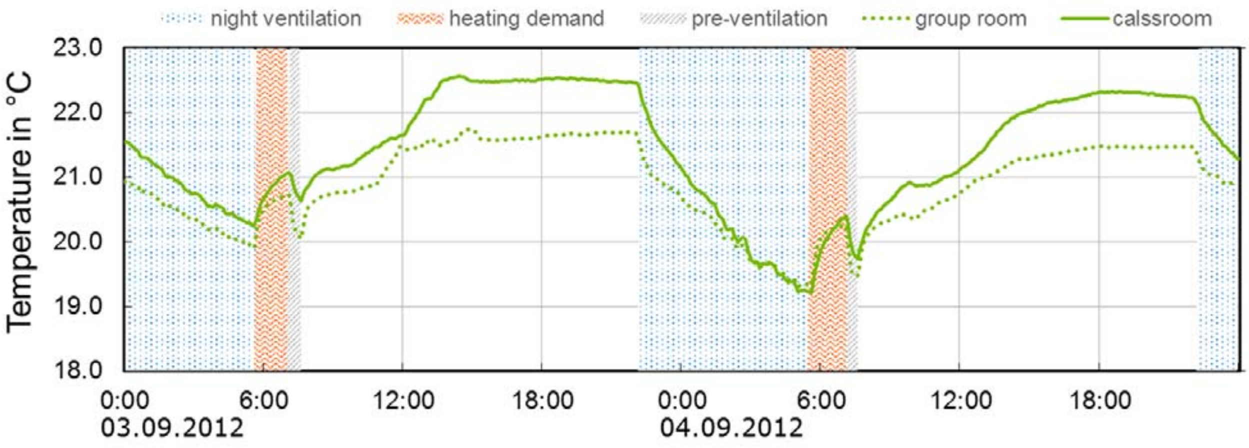

Fig. 3 Time series for room temperatures in class- and group room 4.2 as well as ventilation and heating periods from 03.04.2012 to 04.09.2012.

4. Air quality

CO_2 concentration is an approved measurand indicating interior air quality, and is used here for evaluation of the hybrid ventilation concept.

In the planning stage a target instantaneous value of 1900 ppm was agreed. This complies with a recommended value for naturally ventilated rooms under [2]. Concomitant funded research uses 1500 ppm as a value to compare different ventilation concepts from all demonstration buildings. Both values are evaluated below.

Figure 4 illustrates time series of room air CO_2 concentration and the opening status of the airing panels for a typical school day representing an error-free ventilation mode. The results correspond with dynamic simulation calculations at the planning stage. During lesson times CO_2 concentration increases sharply, but remains comfortably below the guidance values. In break times CO_2 concentration decreases significantly with natural pulse ventilation and hits values around 1000 ppm. This process is repeated throughout the day until occupation ends.

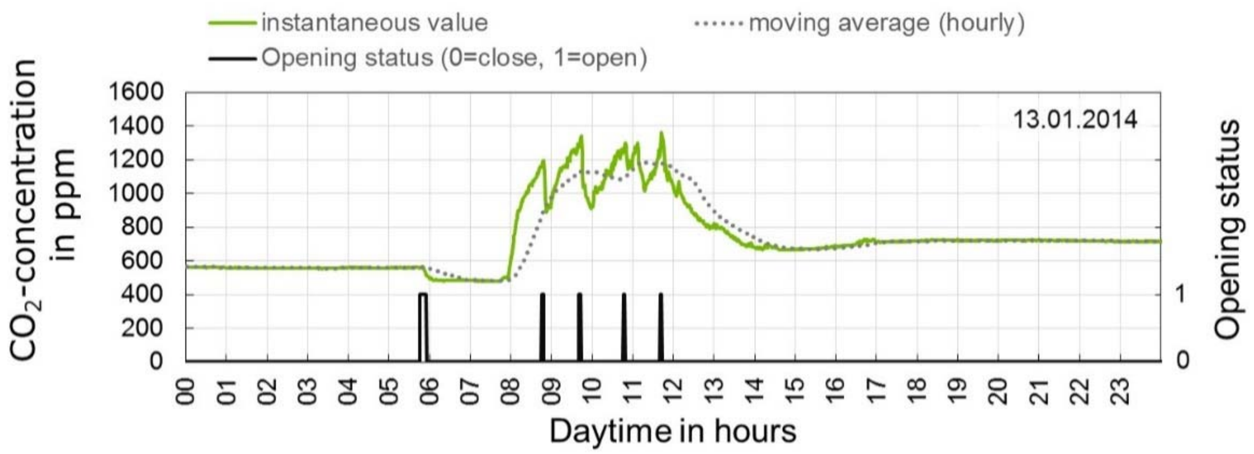

Fig. 4 Exemplary progression of the CO_2 concentration and opening status of the airing panels on a typical school day in classroom 2.2.

These results have been obtained for longer time periods and they show compliance with the target instantaneous value of 1900 ppm. Downtimes of the motorised airing panels, however, have a significant impact, showing widely varying results for different time periods and areas. A comparison is given in Table 3.

Table 3: Annual occupation time regarding different recommended values for CO_2 concentration ($\sigma(CO_2)$).

Room	Classroom 2.2		Classroom 4.2	
School year	2012/13	2013/14	2012/13	2013/14
Total occupation time	888.75 h	879.83 h	860.92 h	1009.67 h
Occupation time with $\sigma(CO_2)$ > 1900 ppm	64.1 h (7.2%)	3.6 h (0.4%)	97.4 h (11.3%)	128.1 h (12.7%)
Occupation time with $\sigma(CO_2)$ > 1500 ppm	168.58 h (19.0%)	67.42 h (7.7%)	235.9 h (27.4%)	307.58 h (30.5%)

1): Opening sequences of motor control unit. Downtimes caused by mechanical defects are not included.

In regular hybrid ventilation mode (classroom 2.2 in school year 12/13) the CO_2 concentration is above 1900 ppm in less than 1% of occupation time and above 1500 ppm in about 8% of occupation time. When natural pulse ventilation is not active, the results worsen markedly. This is particularly the case in classroom 4.2, where CO_2 concentration rises above 1900 ppm in about 12% of occupation time, and in about 30% of occupation time it exceeds the value of 1500 ppm.

The air change rate of natural (free) ventilation system is mainly dependent on pressure, or rather temperature differences between inside and outside air. This correlation implies an inefficiency in the system during the summertime when temperature differences are very small. In the GSHN, data analysis shows that the user counteracts this downside by opening additional windows manually. Hence CO_2 concentration decreases due to higher outside air temperatures, as shown in figure 4.

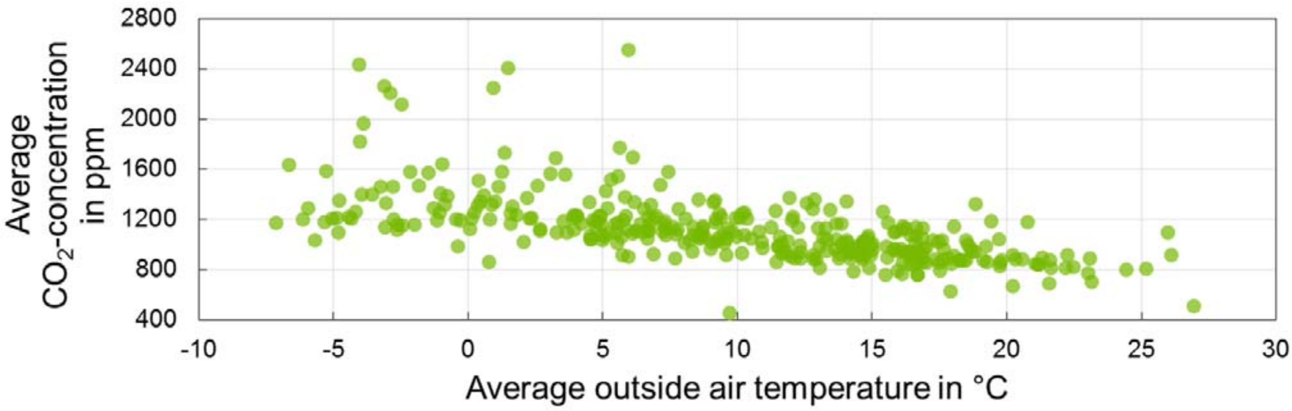

Fig. 5 Daily average CO_2 concentration in classroom 2.2 at occupied days as a function of outside air temperature within monitoring period.

5. Conclusion

Hybrid ventilation concepts which combine natural (free) pulse ventilation and mechanical ventilation have been rarely used in practice, but can achieve good indoor air quality with a minimum of electrical energy consumption.

The hybrid ventilation system of the GSHN obtains, in regular operation, a maximum value of 1900 ppm and undercuts 1500 ppm most of the time. Related literature and norms (see [3]) recommend a more strict instantaneous value of 1000 ppm for CO_2 concentration in teaching areas. This, however, is difficult to achieve with natural pulse ventilation due to the classroom's high occupation rate and comparatively short breaktimes. If a more srict value is desired, systems with continuous fresh air supply are more suitable for those areas.

In practice, the natural ventilation system built in the GSHN is very susceptible to faults, and regular maintanance is essential to ensure trouble-free ventilation. Hence, troubleshooting procedure must be planned at an early stage and technologies used should be robust.

The control strategy, however, can also be improved in regular operation. In particular, the dynamic interaction between heating and ventilation system presents room for improvement, so that unnecessary heating periods can be avoided. Further research is needed on this subject.

Additionally, the implemented weather protection controller frequently disables the natural ventilation function, and energy efficiency of the system can be improved by disconnection of power from motor control units outside operating times, reducing standby consumption effectively.

Natural ventilation allows external, unconditioned air into the building which may lead to thermal discomfort when outside temperatures are low. In order to run the system successfully throughout the year it is important for the user to understand the operating mode. Involvement of the user at a development stage is recommended to produce a suitable ventilation strategy.

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Environmental and Social Concerns in Architectural Education: Experience of School of Architecture, Tianjin University

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Summary

Sustainable design is becoming a major concern in architectural education globally. The highly dynamic construction activities and social development of China has caught global attention. Hence it is of special importance to promote sustainable architecture education, so as to equip the next generation of architects with knowledge and concerns for a better environment and better life of people. School of architecture, Tianjin University has made efforts in this direction with various topics of design studio, such as building in life cycle, the places for urban migrants, and resilient city. We have also tried to combine international experience through joint studios with foreign faculty and students. In this contribution, the topics and methods of the sustainable design studios are demonstrated with prize-winning student works, which made the effort in dealing with the climate, social and economic conditions of China.

Keywords: architectural studio, sustainability, China, social, environmental, life cycle

1. Introduction

The focus on social and environmental issues has been the main themes architectural design idea competitions continue to address. These are also the issues we want our students to consider in their design proposals for the Thematic Design Module (TDM) in the Third- and Fourth-Year undergraduate design studio courses. Over the years, sustainable architecture has become one of the main areas, in which research-based education develops at the School of Architecture of Tianjin University. The main themes of TDM include: Environmental performance optimization under the building life-cycle theory; and Improvement of urban built environment and building function based on social research. Design competitions play an important part in the TDMs. In leading TDM, the tutors either suggest appropriate competitions for students to consider as their design project, or make adjustment to appropriate design competition calls to suit the themes and requirements of the course.

Sustainability is a comprehensive concept. In the six-week design-research studio of the TDM, we have designed a variety of topics, including: “Life-cycle Architecture”, “Bionic Architecture”, “Resilient Cities”, and “Places for Urban Migrants”. The design modules emphasis research-based design and encourage students to study the ecological characteristics of, and the macro social issues around the built environment, in order to develop low-cost and low environmental impact buildings. Hitherto, submitted students’ works from the TDMs have won several awards in a variety of design competitions, including: “UIA HYP Cup International Student Competition in Architecture Design”, “BADI International Green Building Design Competition”, “LANXING Cup National Student Competition in Architecture Design”, “Best Teaching Syllabus of National Higher Education in Architecture”, “UA International Concept Design Competition”, and “Best Students’ works of International Collaborative Design Studios”.

2. Methodology

The aim of the Thematic Design Studio of Sustainable Architecture is to direct the students to observe and create the connection between architecture and its natural environment and social cultural context. It focuses on two key points: 1. To reduce resource consumption and environmental impacts during the life cycle of the building with passive climate design methods, sustainable usage of building matieral, and flexible and adaptable building space and construction system. 2. To observe and analyse the social problem during the urban development, and propose architectural solutions of the problems, in order to enhance social equality and quality of the living and working spaces for common citizens and urban migrants.

2.1 Methods

At the beginning of the studio, the concept and criteria of sustainable design is introduced with case study, so that the students can establish a notion of integrated design. Then the students will learn about the climate design methods and simulation tools, such as Ecotect, Aiapak and simplified LCA tools. There are also lectures and training for social survey methods, such as questionaires, investigation, interview, and data collection and analysis.

According to the objectives, the methods of the studio can be classified as two packages: environmental design methods and social survey.

2.1.1 Improving the life cycle environmental performance

Climate design strategies and simulation tools is a major conern of the environmental design package. Students are encouraged to study local and intermediate technologies under the bioclimate principles, E.g. to promote natural lighting, ventilation and thermal comfort with special and construction solutions. They have also learnt to improve the micro-climate with natural elements such as vegetation and water. Local renewable energy and innovative technologies can be applied on the basis of passive design strategies. Simulation tools of daylighting and CFD are used to support the improvement of the designing solutions.

Sustainable use of building material is an important issue for the life cycle environmental quality. Students are asked to study and use the local, recyclable, renewable and reclaimed materials.

Construction system should be designed with consideration of the potential for refurbishment, transformation or deconstruction.

Spacial and constructional flexibility is another key point of the studio. Students are asked to consider the adaptability to different uses of the functional spaces, as well as heating and cooling zones in differenct seasons.

2.1.2 Urban study and social survey methods

The social aspect of the Themetic Design Studio puts emphasis on the urban migrants who work and live in the city without an official citizenship (which is called *Hukou* in Chinese). This population are doing service jobs, working on the construction sites, or being self-employed as 'grass-root' artists. They provide service to the citizens, but their living condition and social needs have always been overlooked. The students are suggested to choose a certain group of urban migrants, to observe, interview and report their current living and working conditions, and to understand their needs. They also collect and analysed the data collected from literature and survey. On this basis, they will create the conceptual diagrams and propose their design schemes. Finally, they will complete the project with technical solutions and details.

2.2 Schedule

The thematic design studio lasts for 6 weeks. In the 1st week, the directors will introduce the topic and methods of the studio with lectures. Students will start to do the case study, literature study and field investigation. In the 2nd week, the first conceptual design schemes are presented. The 3rd week focuses on training course of simulation and analytical tools and first effort in applying the tools to improve the scheme. In the 4th and 5th week, students will develop their project to the level of construction details and alternative spatial organisation. In the last week, students will finish their models, drawings and illustrations and present their works.

3. Results

3.1 Building in Life Cycle

Figure 1 shows the Second-Prize winning design proposal 'Through the Reed Wall and the Timber Frame: Student Center of Tianjin University' for the "2013 BADI International Green Building Design Competition". The proposed site is a small plot between two adjacent university campuses, which are separated with a wall. On an 8m*8m grid, the proposed students' activity centre aims to provide an open and sheltered space for use by students from both universities (Figure 2). The proposed design considers the use of passive solar, natural ventilation and natural lighting designs. The use of reed as insulation material and partition wall material address the issue of the use of locally sourced materials. Simulation tools were used for the optimization of the wind flow organization and day lighting (Figure 3). Construction details are designed for the eaves and façade.

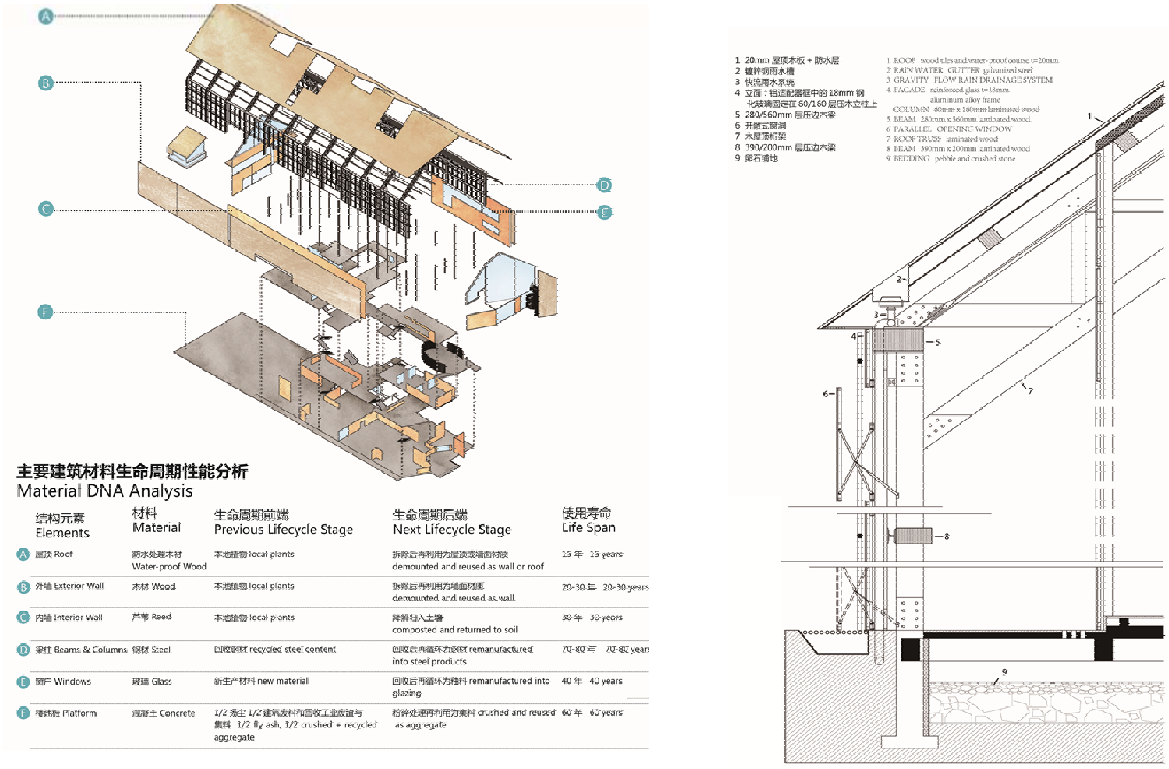

Figure 1: 2013 BADI International Green Building Design Competition Second-prize winning project (Students: LIU Shi Da, CAO Jun Chuan, ZHAO Ke Lun, LI Xiang)

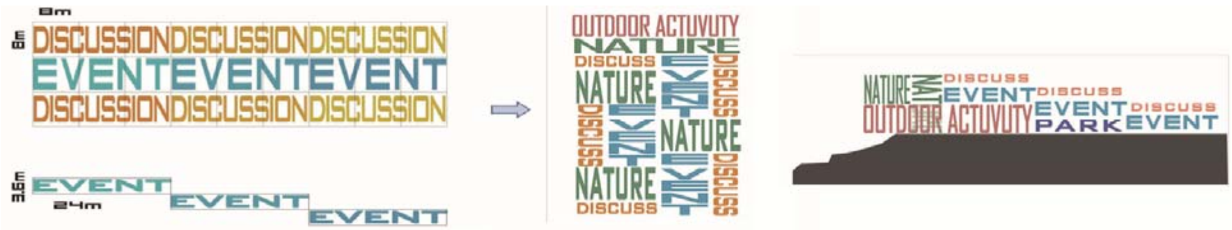

Figure 2: Diagrams for the program and space organisation

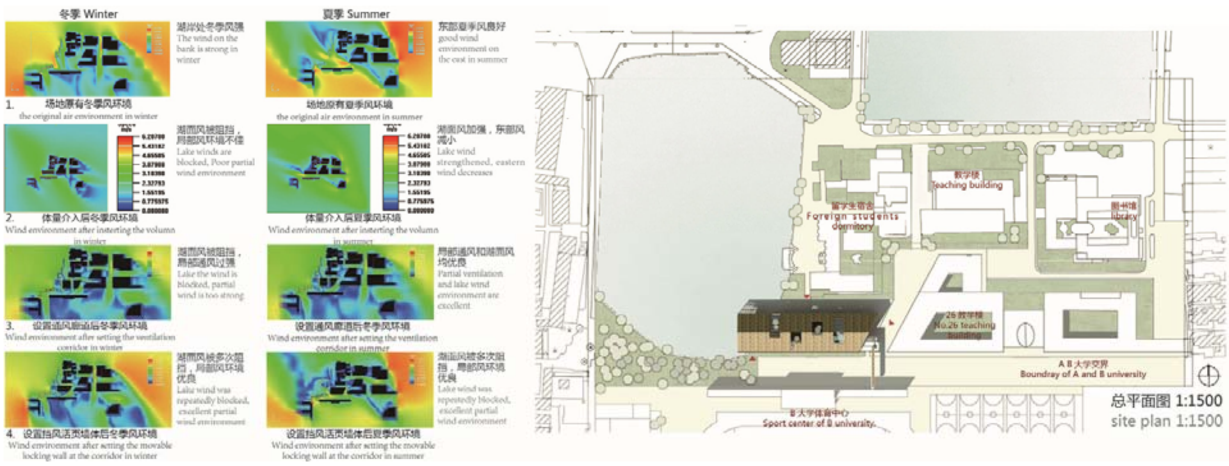

Figure 3: Site plan and the wind flow analysis for the layout solutions

Figure 4 demonstrates the Third-Prize winning design proposal ‘Walking in the Lost’ for “2013 HYP Cup International Student Competition in Architecture Design”. The students’ work was the result of a joint studio with two professors from the University of Minnesota. The proposed design is a camp and research centre for young archaeologists at the historic site in Taklimakan Desert. The theme of this design studio is “Bionic Architecture”. The student chose the desert plant “Fenestraria aurantiaca” (window plant) as an archetype, and studied its climate-adjustment and light-control mechanisms (Figure 5). The detailed study resulted in a series of diagramming to illustrate how light is transferred to the bottom of the plant buried in the sandy desert and how the thick wall and grouping of the plants protects themselves from the hot and dry climate. These gave rise to the final design proposal, which reflects the biological characteristics of “Fenestraria aurantiaca”.

Figure 4: 2013 UIA HYP Cup International Student Competition in Architecture Design Third-prize winning project: “Walking in the Lost”(Student: MUYU Yang Guang)

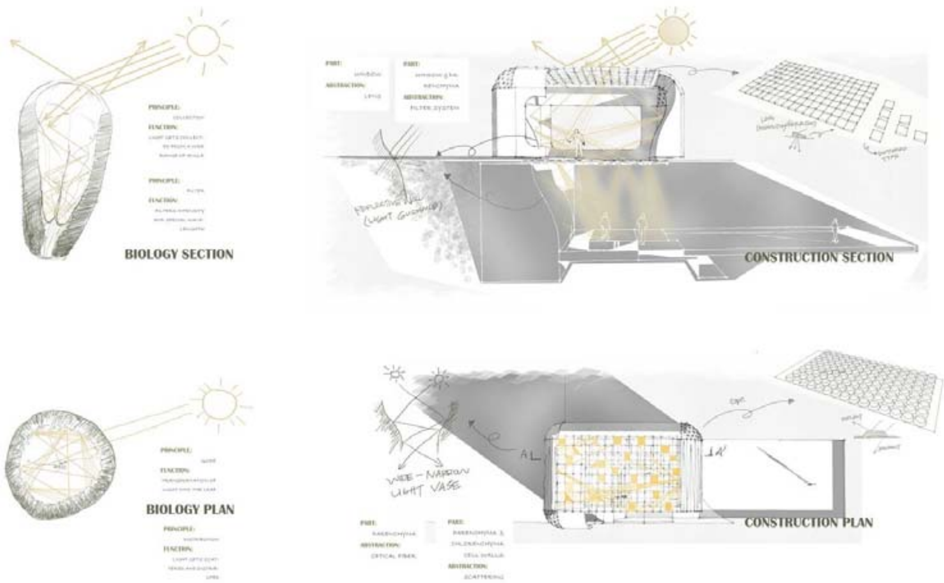

Figure 5: Diagrams showing the transference from plant archetype to architecture design (Student: MUYU Yang Guang)

3.2 Places for the Urban Migrants

Figure 6 “Home for Migrant Workers” conceptual diagramming (Students: ZHANG Yi Fan and LIU Shan Shan)

Figure 7 Construction process of the “Living+Planting” module

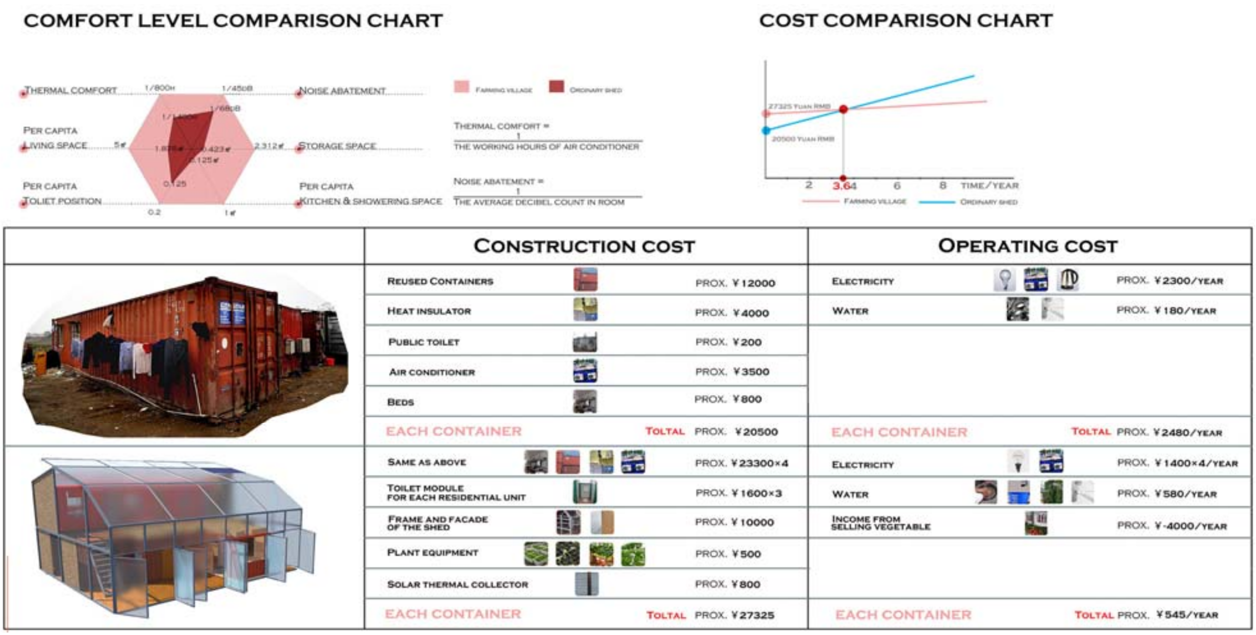

Figure 8: Comparison between conventional and planned container houses for migrant construction workers: comfort level, Initial and opreational costs, and income from planting

The students are required to conduct a survey on the living and working conditions of one type of urban migrants and develop proposals to improve their living and working environment at low costs and with low environmental impacts. The designers of “Homes for Migrant Workers” proposed a new type of temporary on-site dormitory for construction workers (Figure 6, 7). Using containers (a commonly found model for construction workers’ dormitory in the coastal cities of China) as the basic unit, the proposed design redesigned and rearranged the container-dormitories to incorporate the idea of planting (a common skill among migrant worker population) and the sale of fruits & veg, with living and working onsite construction field, to meet a manifested demand among surveyed migrant workers. The result home for migrant workers constitutes a “living+planting” module and a street-front “sales+activities” module. The “living+planting” module celebrates of the identity of and takes advantages of the skills of the construction workers as former peasants; The street-front “sales+activities” module replaces the usual segregation of the billboards surrounding the construction field, and provides a variety of activity spaces for interaction between the construction workers and urban residents. In terms of environmental design, the proposed design considers passive solar design, rainwater collection and the use of waste construction material for planting pots. The initial costs and life-cycle costs are estimated to compare the short and long term cost-benefit of the proposed scheme and the common container houses for the construction workers (Figure 8). The result show that benefits from energy saving and income from vegetable production can payback the additional costs in 3.6 years. And the movable and reusable modules have a life time for more than 20 years. This project won the award for the “Best Syllabus of National Higher Education in Architecture”.

3.3 Resilient City

This Second-Prize winning project “Floating Damascus” (Figure 9,10) was submitted for “2014 HYP Cup International Student Competition in Architecture Design”. The proposed design aims to provide a shelter place in the wartime Damascus. Using modular wooden structure and gridded floating balloons, the structure demonstrates flexibility that suits the needs at the wartime, armistice and postwar times, and provides space for different activities required at each stage. The design considers modular construction and adaptability under different climatic and lighting conditions.

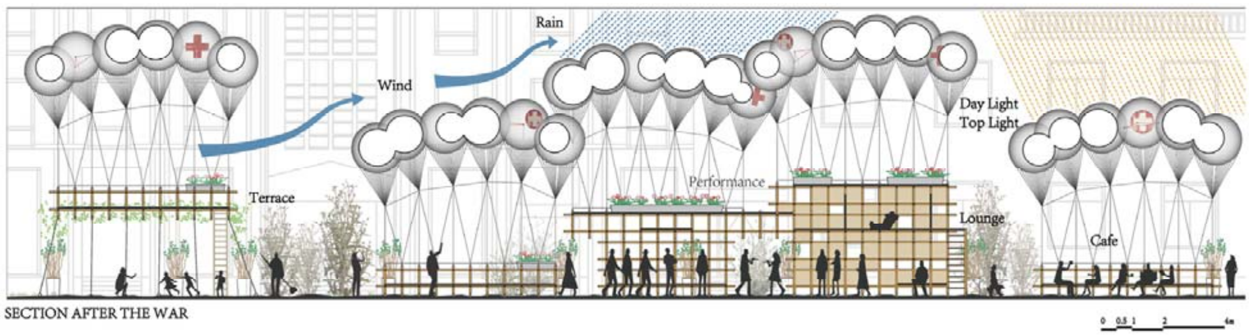

Figure 9 “Floating Damascus” Section diagram (Students: LIU Shi Da, BAI Wen Jia, LI Xiang, WANG Xi)

Figure 10 “Floating Damascus” Function diagram over different stages

In the same competition, the Honorable Mention award-winning project “Future/Canalism” (Figure 11), focuses on the urban traffic and commuting issues of metropolitans of China. Based on a study of the historical development of the water channels of Tianjin, the students designed a new type of vehicle that commutes on the water, in order to lessen the burden on road transportation. The new water vehicle uses renewable energy and mechanical kinetic energy (induced by the act of cycling of commuters on board), and purifies the water as it moves along the network of canals in the city.

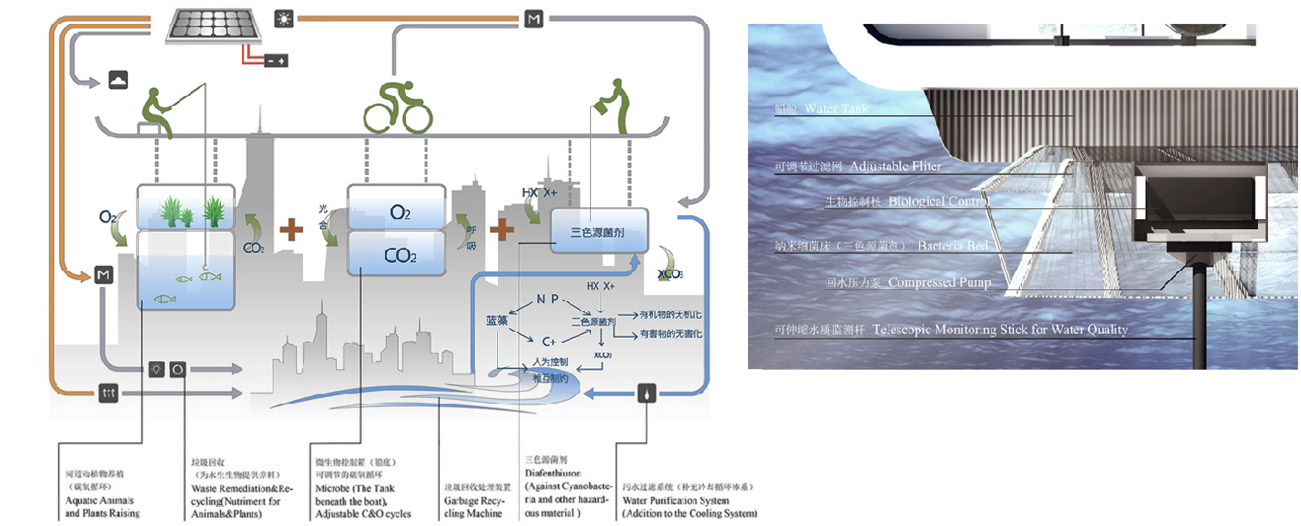

Figure 11: “Future/Canalism” (Students: ZHANG Qi, YANG Ying, WANG Fei)

4. Discussion and Conclusion

(1) “Sustainable Architecture” emphasizes the relationship between nature, society and the built environment and seeks to achieve the integration of function, aesthetics and technology. The major topics of our Thematic Design Studio include building in life cyle, places for the urban migrants and resilient city.

(2) The Thematic Design Studio combines design assignments with the opportunities of student design competitions, and encourages students to compete on the national and international stage. Over the past three years, the students’ works from the studio have won several national and international awards, which demonstrates the importance of the topic.

(3) The Themetic Design Studio encourages students to undertake research in a variety of related areas and propose innovative design solutions based on their research. The unique perspective and creative thinking of the students are valuable for our teaching experience.

(4) Cross-disciplinary and international collaboration have played an important role in the delivery of the TDS. The use of simulation software and analysis tools has also been an important part of the studio.

(5) So far the life cycle perspective of the design studio is based either on simple calculation of the life cycle costs and embodied energy, or on the qualitative analysis. The method can be improved by introducing simplified LCA and LCC tools in the designing process.

5. Acknowledgements

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Minnesota. The student work 'Through the Reed Wall and Wooden Frame' was co-tutored by Dr. Gong Xiao-lei and Dr. Zheng Ying. Dr. Liu Gang, Dr. Guo Juanli, and graduate students from Prof. Liu Cong-hong's studio have helped in technical training and consultancy.

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Environmental performance of urban transit modes: a Life Cycle Assessment of the Bus Rapid Transit

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Abstract

Motorized modes of transportation play a major role in developed societies. As they essentially trade energy against distance and speed of travel, their share in the overall consumption of energy and materials is high, making it reduction an important objective for sustainability. This calls for both the systematic evaluation of environmental performance and eco-design of transit modes. This twofold objective is addressed in the paper, which applies a Life Cycle Assessment (LCA) methodology to a transit mode, encompassing both infrastructure and vehicle fleets. The methodology is applied to a case study of a Bus Rapid Transit (BRT) system in Martinique. The results show the contributions of the project's subsystems and life cycle phases to its environmental impacts, on a set of 13 indicators. Impacts are normalized per passenger-kilometer. Comparison with other modes shows the influence of vehicle occupancy rates and therefore the relevance of demand estimates in ex-ante evaluation. Finally, a sensitivity analysis is conducted on four input parameters, to assess the potential of eco-design for BRT modes.

Keywords: LCA; road transportation modes; eco-design; Bus Rapid Transit; environmental performance

1. Introduction

1.1 Context and objective

The transportation sector is a significant contributor to environmental impacts: In 2010, it accounted for 14% of global greenhouse gas emissions [1], primarily from road transportation. In urban environments, however, the development of new infrastructures that increase passenger capacity through mass transit services, could reduce energy demand from transportation by around 40% over its current level by 2050. Among these infrastructures, one that attracts particular interest is the infrastructure required for Bus Rapid Transit (BRT) systems[1], as an alternative to the private car. The main characteristics of a BRT system are: high-frequency service and greater regularity; higher operating speeds than a traditional bus, with the allocation of a dedicated lane on most of the route and priority at intersections; easy access for people with reduced mobility (station platforms at the same level as the vehicle footbed) and high levels of on-board comfort (movement space, fittings); reliable passenger information. The objective of this study is to carry out an eco-assessment of the BRT transit mode on a specific case study in Martinique, and to compare its environmental impacts with those of other competing urban transit modes. For this BRT mode, we will apply the Life Cycle Assessment method of environmental evaluation.

1.2 Presentation of the research topic

Our case study is a dedicated-lane mass transit (BRT) line in Martinique, a French Caribbean island. This forking line will link the center of Fort-de-France - capital of the island - with the town of Lamentin ("Mahault" interchange hub) and with the airport ("Carrère" interchange hub). It will have 16 stations, 2 interchange hubs, 1 maintenance center (outside the scope of this study) and will be serviced by fourteen 24 meter long hybrid bi-articulated buses. The project will be carried out through a public-private partnership, under which the firm Caraïbus will have a 20 year operating license, and is due to open at the end of 2015. On weekdays, the service will be open from 5:30 am to 10 pm. In terms of service frequency, from 2017 it is expected to run every 6 minutes at peak times (6:30 am-8:30 am and 4 pm-6 pm) on the main trunk line, and once an hour at slack times (after 8 pm), with intermediate intervals of 12 and 30 minutes at other times.

2. Methodology

2.1 LCA and transportation: scientific positioning

Life Cycle Assessment (LCA) is a method whose general framework and guidelines are established in ISO standards 14 040 and 14 044 [2]. It is used to the potential environmental impacts, of a product or service in the course of its life cycle, related to a functional unit with a quantitied and time dimension. Initially developed and formalized for manufactured products or for services, the method's application to the transportation sphere is more recent and has given rise to a number of studies and questions [3]. A number of authors [4][5][6] distinguish 3 types of LCA: (i) "Process LCA" which is the most detailed, and where the inventory is based on the processes (i.e. physical flows) included within the perimeter of the system being studied; (ii) environmental Input-Output (EIO) analysis, in which inputs and outputs are calculated on the basis of national input-output tables which link economic flows for each sector with their environmental impacts; and (iii) "Hybrid LCA" which provides the missing data needed to carry out a Process LCA using the EIO analysis. This third form has been much used in this sphere of road transportation in the USA. France does not have EIO tables.
The LCA of road infrastructures, an avenue opened up in 1996 [7] and punctuated by numerous studies ([8], [9], and [10] to cite only a few), is now a fairly well-defined field. The usage phase has only recently begun to be modeled ([11], [12], [6]). Numerous LCAs have also been carried out on the comparison of bus traction forces ([13], [14], [15], …) or on a standard bus [16], based for example on EcoInvent Life Cycle Inventories (LCI). Similarly, the bus mode has been studied – excluding infrastructure – with the aim of assessing the environmental impact of the traction mode over the life cycle on the basis of the local electricity mix [17]. However, there seem to be no process LCAs for a "complete" BRT line, including infrastructure and vehicles. The study by Chester and Horvath [18] is a hybrid LCA which models an average American urban diesel bus transit mode running on shared roads, taken up by Dave (2010) to compare "average" urban modes in the United States against energy and climate change criteria [19]. Spielmann's study [20] forms the basis of the transportation mode processes in the EcoInvent database and is based on averaged data (Europe or Switzerland). Another study presents the carbon footprint of a BRT line in China using LCA, but it is difficult to understand where the data come from [21].
Our study presents a Process LCA for a BRT line in which the assessment perimeter is wider than in previous studies, and based on industrial data. Our contributions lie in the application of process LCA to a real complex system, together with the creation of associated macroprocesses: earthworks, dedicated pavement, etc.

2.2 Definition of objectives and of the system studied

The aim is to conduct a process LCA for the Martinique BRT line over an observation period of 28 years – corresponding to the infrastructure's structural design – for each subsystem and life cycle phase, and then per passenger-kilometer traveled. The function studied is the carriage of passengers on the line, and the functional unit is "providing passenger transportation on the line for the 28 years of the license, with a 5% level of infrastructural risk at the end of that term". We consider that infrastructure construction – see items in column 4 of Figure 1 – is entirely dedicated to the transportation function. Since the lifespan of a road infrastructure is difficult to establish, we chose a period of observation for which the required maintenance forecasts are precise. In order to relate the impacts to the quantity of service provided, we normalize this functional unit per passenger-kilometer ([19], [14], [16], [18], [20]), on the basis of several line use scenarios.
The system studied and its precise perimeter are described in Figure 1 and Table 1. In the absence of data, maintenances of street furniture, green spaces and sidewalks were excluded.

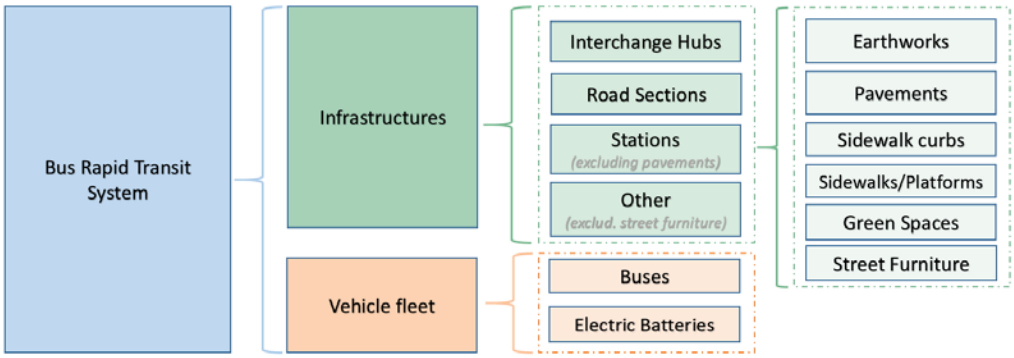

Figure 1 Description of the system studied: model per subsystem (column 3) and per construction batch (column 4)

Table 1 Life-cycle phases considered

Subsystem	***Construction***	***Use***	***Maintenance***	***End-of-life***	***Transportation***
Earthworks	X	////	X*	X*(100)	Included
Pavement	X	////	X	X*(>28)	Included
Sidewalk curbs	X	////	////	X*(>30)	Included
Sidewalks	X	////	////	X*(30)	Included
Green spaces	X	////		////	Included
Street furniture	X	X		X*(>28)	Included
Buses	X	X	////	X (14)	Europe to Martinique
Batteries	X	////	////	X (10)	Europe to Martinique

X* (α)= not necessary over 28 years, lifespan considered = α
//// not applicable

A set of 13 indicators was chosen to cover the main current ecological priorities and the different natural compartments. Energy resource consumption was calculated by the Cumulative Energy Demand method. Solid and radioactive wastes were calculated by the EDIP method. The indicators on climate change, abiotic resource depletion, acidification, damage to the stratospheric ozone layer, photochemical oxidation, eutrophication, ecotoxicity and human toxicity are calculated by the CML 2001 method [22].

2.3 Sources of the life cycle inventory data

The data were provided by industrial partners in the BRT project. We chose to use the OpenLCA 1.3.1 open source software, because it allowed us to use the existing flows in EcoInvent or even to modify and adapt them. The EcoInvent database we used is the benchmark multi-topic database for conducting a LCA in Europe. It contains international industrial data from life cycle inventories on energy supply, resource extraction, chemical products, metals, agriculture, waste management services and transportation services.

2.4 Assumptions

The quantitative estimates were made on the basis of the Caraïbus partnership dossier, the Indicative Bill of Quantities provided by Eurovia, and documents from VanHool. We assumed building machines are used 7h/day, and its diesel consumption data are drawn from special databases (from SEVE and Gaïa, supplied by Eurovia), which take account of idle times. Depreciation on the building machines is not taken into account. The work rates are provided by Eurovia. The electricity mix chosen is, as a first approximation, that of Poland, which is very close to Martinique's, with some 95% coming from a thermal source. Unless otherwise stated, we exclude the transportation of materials before they reach the suppliers. The distances from supplier to site were either provided by our industrial partners, or calculated from the supplier list using Google Maps. For the road sections and stations, we take the barycenter of the total route as the starting point for calculating the distances from suppliers. Supplies are brought to the construction site in EURO4 standard 16-32 tonne trucks, except for the green spaces.
The fleet consists of forteen 24 meter long bi-articulated buses, with a lifespan of 14 years. Because the percentage of unidentified materials in VanHool's data was too large relative to the cut-off threshold tolerated by standard NF P 01-010 (98%), we used EcoInvent's life-cycle inventories for bus construction, maintenance and end-of-life: we identified the materials and processing procedures relating to the thermal engine, then we carried out an initial LCA calculation proportional to the total masses of the VanHool bus and the EcoInvent bus, deducting the mass of their thermal engines (not proportional to the mass/size of the bus). We then complemented this with the process for the electric battery on the hybrid system ("*electric motor, electric vehicle, at plant, RER*"). From the mass of the battery, we calculated the mass ratio between the electric cells and the rest of the battery, drawing on the expert views of the French manufacturer Opel (which corroborate the data in the study by Li et al. [23]), and drew on the literature for data on the battery materials other than the electric cells [23]. We assumed the batteries to have a lifespan of 10 years, thus giving us 3 sets of batteries per bus, but 2 ends of life for our 28 year period of observation. With regard to bus usage, we considered two phases: a commissioning phase from 2015 to 2017 with 56 trips per day, then traffic growth of 0.42% per year over 26 years with, in 2018, 69 runs on the common trunk of the line in each direction and on each day, together with consumption measured on a SORT cycle of 56L/100 km. We adapted the "*operation, regular bus, CH*" process to the consumption and emissions (for NOx, CO_2 and CO) of the VanHool bus, measured by the World Harmonized Stationary Cycle procedure.
Of the line's total 15 km, 12.5 km were already built. Eurovia is building the remaining 2.5 km, as well as all the stations. We considered in our study that the 15 km were built and maintained in accordance with Eurovia's technical choices. The volumes of materials in the concrete components were calculated from standardised product sheets. The scaling and maintenance assumptions were provided by Eurovia. The factors systematically ignored are the different elements not quantified in the indicative BOQ, and small equipment that can be reused.
The "street furniture" item includes the production of the equipment, its transportation, and the energy consumed by the streetlamps and access barriers. When no specific data was provided, we chose the standard elements from supplier catalogs, conducted a materials assessment and selected the most appropriate EcoInvent processes, as far as possible including manufacturing processes. For the lighting, the batch consists of 1 streetlamp every 250 meters in each direction on road sections, switch cabinets, electric cabling and station lamps. For each station platform, this category includes a bus shelter, 4 benches, a CCTV pole, 2 trash cans, a switch cabinet, lighting and railings. Each interchange hub has 10 cycle racks, barriers, and 10 tree and streetlamp protection hoops. The materials assessment for the streetlamps was based on the catalog of the supplier Alunox, the assessment for the LED lamps (stations and hubs) and for the ONYX bulb lamps from the Eclatec catalog (road sections) using CEGELEC data, and the assessment of the switch cabinets on the basis of the Environmental Product Profile for Schneider Electric's Prisma Plus cabinet. The materials assessment for the bus shelters is extrapolated from the Techni-contact catalog. Each lamp operates for 4500 hours a year, with wattage of 50W for

the LEDs and 250W for the ONYX lamps. The total consumption of the automatic barriers is 15,000 kWh. Finally, it is assumed that all except the concrete elements are made in France at Clamart. They are shipped by road to the Port of Le Havre, then by boat to Martinique.
In the green spaces category, we included the laying of the topsoil, the plantings and their street furniture, separators, painted markings… The concrete crash barriers are supplied by SATRAP, The crash barriers by GETELEC, the signage equipment and by SERR. The planting spoils are transported 20 km and the topsoil 25 km. Each tree planted weighs 200 kg, the turf is supplied in rolls (6 kg/m²). In the green spaces, trash cans, cycle racks, and streetlamps are made of steel.

3. Results

3.1 Global results per subsystem

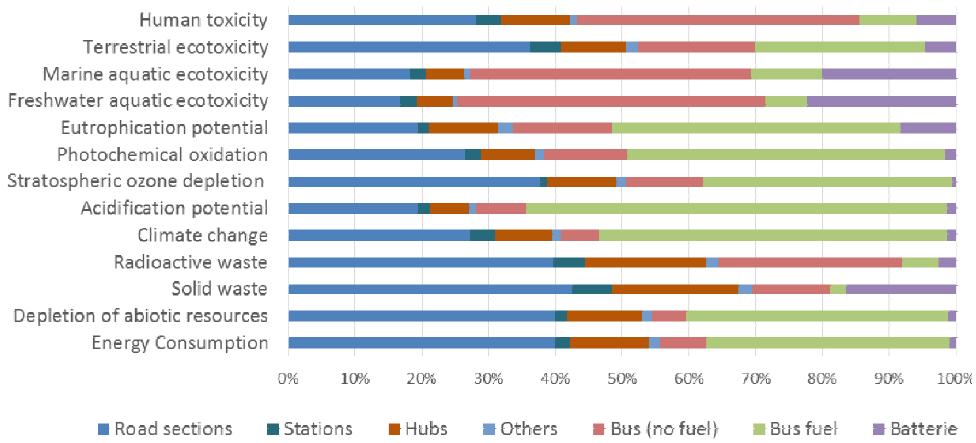

Figure 2 Contribution of each subsystem to the different impact categories

Figure 2 shows the contributions of each subsystem's environmental impacts. The "other" category covers the traffic circle and emergency exits. Three subsystems contribute particularly to the majority of the impact categories: the road sections, the buses and the fuel they consume. The electric batteries in the hybrid bus system also make a significant contribution to the impacts, with 16% for the solid waste indicator – linked with the current difficulty of recycling batteries – and respectively 22% and 20% for marine and freshwater aquatic ecotoxicities.

3.2 Results per item group

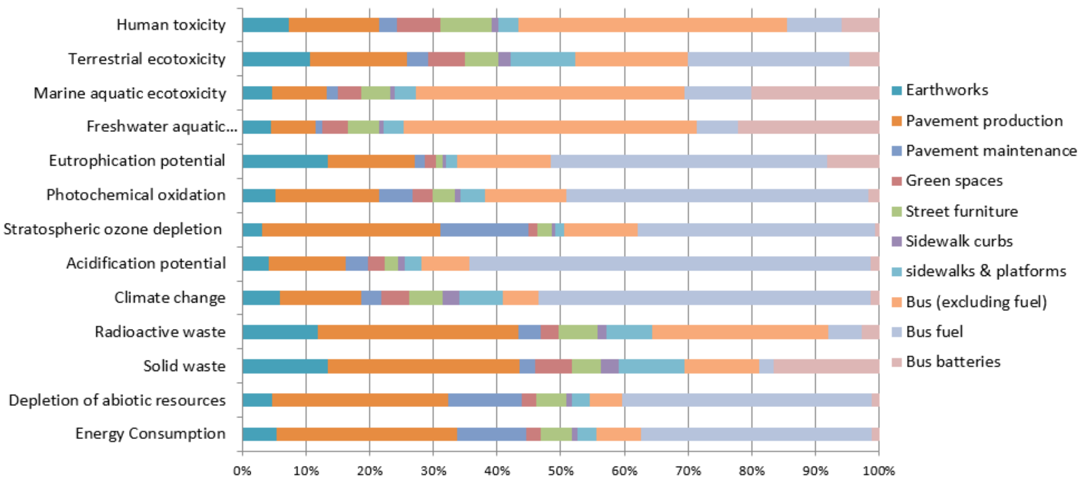

Figure 3 Contribution of each subsystem to the different impact categories

Alongside Figure 2 , Figure 3 shows the respective contributions of the street furniture, the green spaces and the phases of earthworks, pavement production and maintenance, sidewalks and platforms. The impacts of the “green spaces” and “street furniture” item groups are low (never exceeding 8%). In terms of infrastructure, pavement production generates the greatest impact – some 30% of energy consumption, of the depletion of abiotic resources, of wastes, and of ozone layer destruction. Nevertheless, pavement maintenance is not insignificant, since in terms of energy consumption and resource depletion, it represents more than 10% of the impact sources.

3.3 Focus on the vehicles

Figure 4 shows the contributions of each phase in the life cycle of the bus, with a separate category for batteries. It is noteworthy that the production of the buses, their energy consumption during the usage phase, and the production of the batteries are the three items that account for most of the environmental impacts. While the impacts of the batteries are very low – less than 5% – in terms of photochemical oxidation, stratospheric ozone depletion, acidification and climate change, they nevertheless generate a significant proportion of the bus line’s (eco)toxicity effects (between 10 and 30%), as well as 53% of the solid waste. The fuel consumption item accounts for 82% of primary energy consumption, 86% of natural resource depletion, and also seems to be preponderant in the indicators for eutrophication (65%), photochemical oxidation (77%) stratospheric ozone depletion (76%), acidification (88%) and climate change (88%).Bus production has a particularly high impact on human toxicity (70%), and on freshwater (56%) and marine (52%) aquatic ecotoxicity. The environmental impacts of bus maintenance are generally low, with the exception of radioactive waste production, in which it accounts for 60% of the effects.

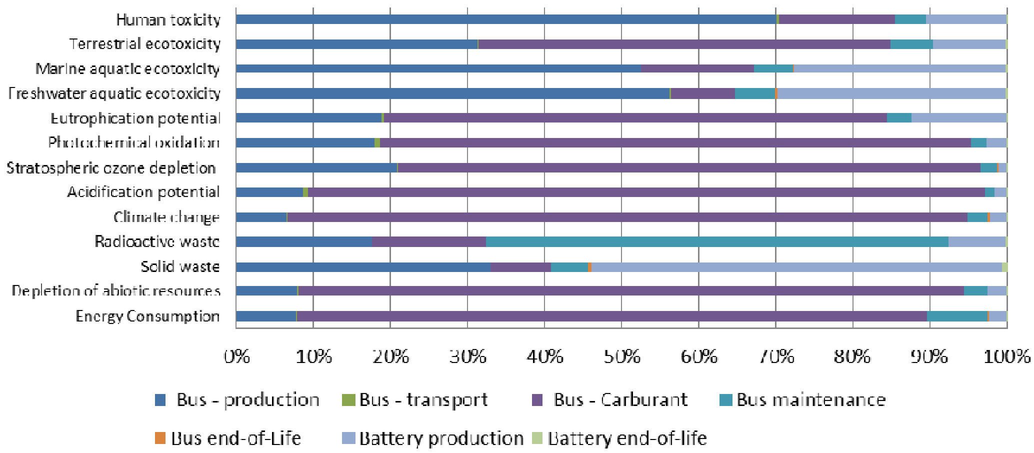

Figure 4 Contribution of each phase in the life cycle of the bus and its electric batteries

3.4 Focus on street furniture

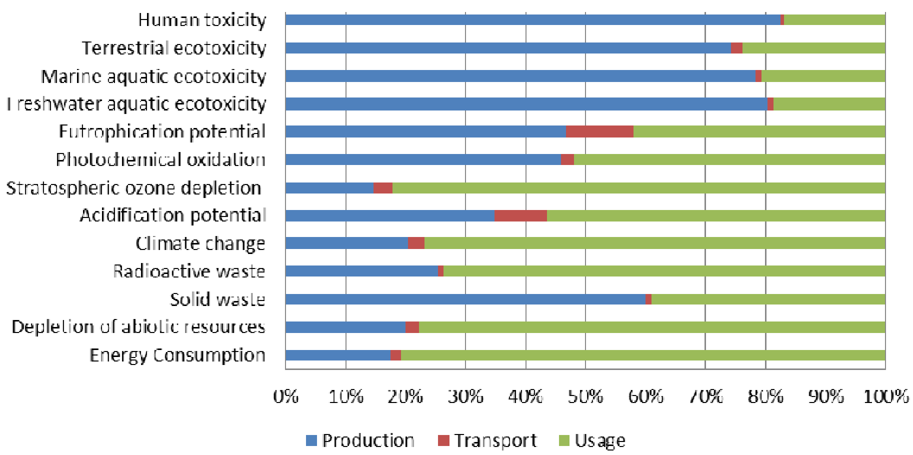

Figure 5 Contribution of each street furniture life-cycle phase to the different categories of impacts

Figure 5 identifies the contribution to environmental impacts of each life-cycle phase of the street furniture. The use phase, e.g. consumption from lighting, is preponderant on many indicators.

3.5 Normalization based on level of use, and multimodal comparison

Table 2 Environmental impacts of the line normalized per passenger-kilometer over an observation period of 28 years based on the average occupancy rate.

Impact category	*Impact/pkm with average occupancy rate (%)*			*Unit*
	82%	**50%**	**30%**	
Energy consumption	4.66E-01	7.64E-01	1.27E+00	MJ eq
Climate change at 100 years	2.23E-02	3.66E-02	6.10E-02	Kg CO2 eq
Depletion of abiotic resources	1.89E-04	3.10E-04	5.16E-04	Kg Eq antimony
Solid waste	2.04E-03	3.35E-03	5.59E-03	kg
Radioactive waste	5.86E-07	9.62E-07	1.60E-06	kg
Acidification potential – generic	1.47E-04	2.42E-04	4.03E-04	Kg SO2 eq
Stratospheric ozone depletion	4.68E-09	7.67E-09	1.28E-08	KgCFC11 eq
Photochemical oxidation	4.99E-06	8.18E-06	1.36E-05	kgEthyleneEq
Eutrophication – generic	3.93E-05	6.45E-05	1.07E-04	kg $PO4^{3-}$ eq
Freshwater aquatic ecotoxicity at 100 years	3.66E-03	6.00E-03	1.00E-02	kg1.4DCBeq
Marine aquatic ecotoxicity at 100 years	1.46E-02	2.39E-02	3.99E-02	kg1.4DCBeq
Terrestrial ecotoxicity at 100 years	5.30E-06	8.70E-06	1.45E-05	kg1.4DCBeq
Human toxicity at 100 years	8.83E-03	1.45E-02	2.41E-02	kg1.4DCBeq

We performed a normalization of the impacts per passenger kilometer, under three scenarios: optimistic, moderate and pessimistic. As Table 2 shows, for the optimistic scenario, each passenger-kilometer would require an average energy consumption of 0.76 MJeq and would have an impact on climate change of 37 gCO_2eq. In order to provide factors of comparison with the transport modes previously used on the route covered by the BRT line, these impacts could be compared with those of other modes. In the absence of spatialized data, as an example, we compare them by analyzing the EcoInvent processes corresponding to different competing modes with fixed occupancy. The levels of impact of the Martinique BRT in terms of energy consumption and climate change per passenger-kilometer, even in the case of the pessimistic scenario, are around 3 times lower than that of the private car (3.34 MJeq and 0.197 kgCO2eq) in European conditions, lower (respectively by 25 and 60%) than the standard bus (1.67 MJeq and 0.104 kgCO2eq) and slightly lower than the trolleybus mode in Swiss conditions in respect of energy consumption, but more than 2 times higher in terms of climate impact, and higher than the tramway. However, the BRT mode can only compete in terms of capacity with the tramway if the BRT has a high occupancy rate: with an average occupancy scenario, the BRT achieves 45% less energy consumption per passenger-kilometer, and lower consumption and emissions (respectively 60% and 25% less) under the optimistic occupancy scenario.

3.6 Sensitivity tests

We have just shown how sensitive the environmental impacts of the service provided by the BRT are to the average occupancy rates of the buses. However, the model's results are sensitive to many other parameters: to the expected lifespans of the subsystems, to the fuel consumption of the buses, to lighting… We conducted a number of trivial sensitivity analyses in order to quantify this roughly. First, our model allocates to the BRT the impacts of a streetlamp every 250 m in addition to the station lighting. In reality, the dedicated lane runs alongside existing mixed traffic lanes which also require lighting (one street lamp every 25 m). Under this hypothesis, its impacts would be much greater, between 3% and 20% depending on the indicator studied. The assumption regarding the bus's consumption is also important to the accuracy of the results: if it is reduced from 56L/100km to 42L/100km (consumption of a similar transit system in the city of

Metz, France), the environmental impacts diminish by 10% on 2/3 of the indicators. On the other hand, increasing the use duration of the buses would only have a small impact on the total balance, as would the use of batteries lasting only 5 years instead of 10 – except on the solid waste production indicator and the aquatic ecotoxicity indicators (Table 3).

Table 3 Variation in the impacts per passenger-kilometer relative to the base model

Scenario	***Base***	***Streetlamp /50 m***	***Bus used 18 years***	***Batteries used 5 years***	***Cons. 42L***
Energy	1	+16%	-0.39%	+1.1%	-9.0%
Abiotic resources	1	+15%	-0.16%	+1.1%	-9.8%
Solid waste	1	+13%	-0.23%	+16.5%	-0.6%
Radioactive waste	1	+19%	-2.37%	+2.7%	-1.3%
Climate change	1	+17%	-0.24%	+1.3%	-13%
Acidification potential	1	+6%	-0.10%	+1.3%	-16%
Stratospheric ozone depletion	1	+7%	-0.12%	+0.6%	-9.3%
Photochemical oxidation	1	+10%	-0.14%	+1.7%	-12%
Eutrophication potential	1	+3%	-0.24%	+8.2%	-11%
Freshwater aquatic ecotoxicity	1	+13%	-0.56%	+22.2%	-1.6%
Marine aquatic ecotoxicity	1	+12%	-0.53%	+20.0%	-2.6%
Terrestrial ecotoxicity	1	+15%	-0.29%	+4.7%	-6.3%
Human toxicity	1	+20%	-0.25%	+5.9%	-2.1%

4. Discussion

4.1 Scope of our results

We draw up an environmental assessment of the BRT mode on the entire life-cycle of the project. The asset of using LCA is to identify impact hotpoints in order to improve the ecological performance of the mode. The elements with the greatest impact are the road sections, the buses and the fuel they consume. With regard to the infrastructure, the pavement contributes the most to the impacts measured by the indicators: around 25% of total primary energy consumption, depletion of abiotic resources, and solid waste, amongst other impacts. With regard to the street furniture, the largest share of the impacts comes in the use phase (through consumption from lighting). Normalization of the impacts and their comparison with other transit modes show that in a comparative approach, the environmental balance of a transportation project greatly depends on its success with user populations. Despite uncertainties, this study addresses the question of eco-designing a BRT mode. Given the importance of the pavement construction, it would be interesting to understand which processes have the greatest impact, so that they can be optimized. Similarly, consumption associated with lighting plays a not insignificant role, suggesting the possibility of improvements to the bulbs used.

4.2 Current limitations of LCA as a decision-making tool in the transportation sphere

The limitations of this study are primarily those of LCA as a decision support tool: restricted to a set of ecological indicators, omitting local indicators (landscape, noise, odors…); its implementation entails uncertainties; its results obviously depend on the choice of the boundaries and the hypotheses, and vary depending on the degree of specificity of the model (e.g. via spatialization of the data). Next, the limitations are linked specifically with our working hypotheses: the choice of a period of observation, the definition of the system and its development over 28 years. On the latter point, the assessment is retrospective on construction, but prospective on system operation: traffic levels, system's real maintenance and consumption needs are uncertain. Numerous questions arise from this study. First, what is the feasibility of this kind of process LCA for the stakeholders associated with a transportation project? The current cumbersome nature of the processing, combined with the very high need for data, cause problems for a systematic analysis. The EIO method reduces the time needed for conducting environmental assessments, while maintaining a wide assessment scope, but can only be used to conduct an assessment on average over the territory covered by the input-output matrices. Then, how to coordinate the implementation of the LCA? The need for very detailed data in a process LCA demands the involvement of numerous actors: manufacturers, designers, subcontractors, etc. Finally, at what point should a LCA be conducted? A ex-post LCA is more precise than a prospective one, but at that point it is too late to optimize most of the choices about the transportation project. As LCA is rather a comparative tool, it would have been more relevant to use it on technical variants. Neverthless, we did not get such data.

5. In conclusion: our recommendations for broadening the scope

In current conditions, the existing life cycle inventories can be used to compare the environmental performance of transit modes on a wide scale like that of a country. LCA-based tools can thus be used by mass transit passengers to compare several routes from an environmental point of view [24], or else by companies to calculate the environmental impacts caused by the traffic they generate [25]. Nonetheless, there exists no tool to guide investment in transit systems or to optimize transit systems in a global manner. One possible avenue of implementation in public policies would be to produce more spatialized inventories associated with transit projects and to insert them into a multimode LCA transportation tool, with a user-friendly interface and a number of default data, which could be modified by the user to represent specific cases. This would facilitate faster implementation of LCA studies by both clients and contractors. It seems important that the results should include an estimate of uncertainties and variability, depending on the input and for each indicator, as shown by our handful of sensitivity tests – at least for use in "expert" mode if the software offers several levels of use. The prospective dimension of the tool would also seem to be a crucial advantage when seeking to rationalize a technical choice relating to objects with long lifespans, whose characteristics and therefore environmental impacts are likely to change over time. Such an instrument would enable decision-makers to assess the environmental dimension of the planning and operation of their transit system against a range of selected criteria. It would also be interesting to be able to incorporate the social and economic dimensions into a more global assessment tool, not solely restricted to the LCA methodology.

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Environmental product declaration (EPD) for sustainable construction - new challenges

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Summary

The European standard EN 15804:2012+A1:2013 [1] for EPD in construction was first publicly available in 2011, it was amended in 2013 and today almost all European Program Operators (PO) have committed to apply the standard. Alone in Germany > 2000 datasets are publicly available for construction products. However, as expected, the practical implementation is still struggling. European POs have founded the eco-platform (www. eco-platform.org) in order to overcome difficulties in a concerted way. The first step is achieving a high common quality of EPD, by common verification procedures and qualifications. Next step will be the common applicability for sustainable construction, e.g. for national databases and building rating tools.

CEN TCs for harmonised product standards specify the horizontal technical requirements in EN 15804 for their individual product groups, e.g. CEN TC 175 “round and sawn timber”. The specifications of one TC often also address issues significant to other TCs, e.g. how to deal with biogenic carbon. To support this intricate net of requirements CEN TC 350 will finalise in 2015 a guidance document answering a collection of questions resulting from practical application.
Strategic issues of global impact are addressed together with trade-offs by discussing new indicators (toxicity, land use and biodiversity) thus providing a new product performance perspective next to the energy dominance of the common LCA applications.

Keywords: EPD, LCA indicators, construction, standardisation.

1. Introduction

This contribution details the results of research supporting standardisation activities in the field of sustainable planning, construction and operation of buildings funded by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. The research was focused on the support and development of standards within the standard families of ISO/TC59/SC17 „Sustainability in buildings and civil engineering works“ and CEN/TC 350 „Sustainability of construction works“. An overview of the activities and results can be seen by the following links:
http://www.iso.org/iso/home/store/catalogue_tc/catalogue_tc_browse.htm?commid=54836&development=on
http://www.iso.org/iso/iso_technical_committee?commid=322621
http://portailgroupe.afnor.fr/public_espacenormalisation/CENTC350/index.html

The standardisation projects are not finalised yet. The international standardisation (ISO) as well as the European standardisation (CEN) are still engaged with some of the tasks. The co-operation between the two levels of international work is rather good. On one hand on the global ISO level more general projects are dealt with, whereas the work on European level has successfully introduced more specific requirements into the standards while still adhering to the general requirements defined in ISO. This can be seen best concerning the “earliest” standards ISO 14025:2006, [2], ISO 21930:2006 [3] and EN 15804:2012+A1:2013 all dealing with Type III environmental product declarations, EPD. Today ISO 21930 is under revision as ISO CD 21930:2015, [4] Sustainability in buildings and civil engineering works — Core rules for environmental declaration of construction products and services used in any type of construction works, with the explicit goal to comply with EN 15804 and develop it further.

Recently the European Commission DG Environment has introduced with “The Single Market for Green Products Initiative and Product Environmental Footprint” (in the following text referred to as PEF) an approach similar to EPD also based on ISO 14025:2004. This has stimulated further discussion of extending the scope of EPD for the European construction sector by introducing new indicators.
A joint working group including the building level and the product level was installed in order to evaluate the applicability of existing methods for addressing more environmental impacts than those included in EN 15978 [5] (building level) and EN 15804 (EPD, product level). This evaluation will be documented in a Technical Report, today registered as WI 00350023 [6]. “Sustainability of construction works — Additional environmental impact categories and indicators — Background information and possibilities”, Evaluation of the possibility of adding environmental impact categories and related indicators and calculation methods for the assessment of the environmental performance of buildings”.

The development of Product Category Rules (PCR) for EPD of specific product groups by individual technical committees for harmonised product standards requires a thorough check on the horizontal level. More than 10 years experience with EPD (French standard 2004 NFP 01-010 Environmental quality of construction products — Environmental and health declaration of construction products [7]) meeting the EN 15804 standard, as well as the new PEF calculation rules just tested by PEF pilots, have challenged some of the consensus found with the standard for the horizontal calculation rules for construction products. In consequence the European standards organisation with its technical committee CEN TC 350 WG3 (product level) has developed new guidance for the implementation of EN 15804:2012+A1:2013. Questions coming from Program operators (POs), Life Cycle practitioners, manufacturers have been discussed and answered among the experts who wrote the standard. This living document can be found at:
http://portailgroupe.afnor.fr/public_espacenormalisation/CENTC350/table_questions_and_answers_EN_15804_june_2015.pdf
In addition a Technical Report addressing mainly product TCs developing the specific requirements for their product group and going through all clauses of EN 15804+A1 is about to be finalised (spring 2016), WI 350020 “Sustainability of construction works — Guidance for the implementation of EN 15804”[8].

2. Additional Indicators

2.1 Why additional indicators and which?

With the gradual shift in the relative environmental importance of a building’s energy use, the need to consider other types of environmental impact, such as human and eco toxicity, land occupation impacts of the building during its life cycle and land transformation impacts related to the

provisioning of raw materials for building materials (e.g. sand, gravel, clay, ore and wood) will become more apparent and increasingly important.
Next to the above statement the draft technical report (WI 00350023) cites a number of policies related to the construction sector which consider the use of the following impact categories that are not covered by the CEN TC 350 standards on EPD today:

a) EU level

1) The Single Market for Green Products Initiative and Product Environmental Footprint
2) The ‘Resource Efficient Buildings’ study for the 'development of a common EU framework of indicators for the environmental performance of buildings'
3) The construction products regulation BWR7

- ecotoxicity for aquatic fresh water;
- human toxicity - cancer effects
- human toxicity – non-cancer effects;
- particulate matter/respiratory inorganics;
- ionizing radiation – human health effects;
- acidification;
- land transformation.

b) Member States

1) Belgium:
From 2017 the following additional impact categories and related indicators will be regulated provided there is a methodology in CEN/TC 350 or in the Product Environmental Footprint (PEF) method:

- Human toxicity (cancer);
- human toxicity (non-cancer);
- particulate matter;
- depletion of resources (water);
- ecotoxicity (soil);
- eco-toxicity (marine);
- land use (soil quality and biodiversity);

2) France:

- Pollution of air and water (method: XP P 01-064/CN [9]);

3) Netherlands:

- Human and eco-toxicity (method: as documented by CML).

Furthermore a CEN TC 350 workshop on additional environmental indicators held 24-25/06/2014 showed that the existing building certification schemes already address some of the indicators, mainly human toxicity and land use. However the assessments are as a rule not performance based and use completely different approaches.
Including new indicators like an indicator on toxicity on the standardisation level will satisfy a demand from society to understand better safety or risks connected to construction products.

2.2 Criteria for the evaluation of potential indicators

Based on the CEN workshop outcome the joint Working group of CEN TC 350 investigated whether the following environmental impact categories for indicators would be fit for standardisation:

- human toxicity (cancer and non-cancer effects);
- ecotoxicity (terrestrial, freshwater and marine);
- particulate matter formation (or respiratory inorganics);
- ionizing radiation (human health and ecosystem health);
- land use (occupation and transformation);
- biodiversity;

- water depletion/scarcity.

The criteria applied are very similar to those developed by the Joint Research Centre (JRC) in Ispra for the recommendation of characterisation models for Life Cycle Impact Assessment (LCIA), adapted somewhat to the standardisation context:

- environmental relevance both at building and product level?
- performance assessment possible?
- Quantifiable?
- Scientifically robust and adequate certainty possible?
- Applicability of the life cycle impact assessment method/model?
- Stakeholder acceptance of the impact assessment model given?

When this article was written, the evaluation by CEN TC 350 based on these criteria was not finalised, it can be expected in mid 2016.

With respect to indicators this contribution focuses on toxicity and land use. Among the other indicators ionizing radiation is not considered a main driver for the impacts from construction products. The production of radioactive waste from electricity generation is already accounted for. Water scarcity is seen as relevant and is basically dealt with using the recently finalised ISO 14046:2014 [10] “Environmental management -- Water footprint -- Principles, requirements and guidelines”.

2.3 Toxicity

The most urgent and also most controversially discussed environmental impact categories are human and eco toxicity and those connected to land use. The referenced ideas, concepts and limitations also apply for eco toxicity.

For human and eco toxicity the favoured method classified as level II/III in the ILCD handbook 2011 [11] is USEtox (UNEP-SETAC-toxicity-model). Based on a fate – exposure model, USEtox, represents the current consensus: In the USEtox consortium personal co-operation of the working groups for CML, ReCiPe und Impact 2002+ took place. Therefor it may be expected that the methods CML 2002, ReCiPe 2008 and Impact 2002+ will be more or less phased out.
The metal industry has strong objections to the application of USEtox for construction products. The main reasons are the characterisation models’ failure to address different speciation of metals, as well as the facts that biodegradation and essentiality are not dealt with appropriately for metal compounds, the toxicity data used is very heterogeneous and the overall lack of inventory data for other than metal related substances gives rise to a negative bias for metal compounds.
The reason for the lack of inventory data may be that there was no comparable general regulation for emissions as for energy related emissions in the respective clean air acts. Today manufacturers have produced homogeneous and verified data on emissions as well as exposure scenarios under the REACH regulation, but this data cannot be directly applied in LCA. It is linked to a substance’s performance, not to the processes of a substance’s (product) system i.e. raw material acquisition, manufacture, use, end of life as needed for an LCA. However new approaches utilising REACH are coming (e.g. ProScale, see below) and might complement an improved USEtox indicators system

The assessment of health impacts due to particulate matter was addressed separately as there are special characterisation models available. While the choice of the actual model did not give rise to controversies, the lack of inventory data e.g. for the construction stage is seen as a problem. The ILCD handbook published characterisation factors according to Humbert.

Both workshops identified serious drawbacks of the application of LCIA toxicity indicators, partly due to lack of consistent data for the intrinsic toxicity and the LCI, partly due to methodological deficiencies. The overall results of the workshops are summed up as follows:

- There is a political demand (PEF) to use LCA based indicators also for describing the toxicity potential of a product system. The CPR requires the consideration of the full Life Cycle of the building and provision of appropriate information on product level.
- LCA based indicators are not applied for toxicological aspects in the existing practice of building assessment. Here risk or hazard based classifications of construction products' ingredients or emissions from such products are used to develop green or black lists of products.
- Industry would prefer to move away from the green and black lists and use performance-based indicators on building level. This means that a certain level of toxicity potentials would not be exceeded, leaving - within these limits - room for different architectural solutions. Operators of building rating schemes support this idea. The indoor air quality assessment however will address measurements of VOC rather than LCIA due to existing regulation and sufficient and consistent data, once there is an agreement how to declare the results from the harmonised testing methods.
- While the evaluation of the JRC / European platform on LCA of how to handle toxicological impacts using LCA methodology was considered relevant and useful, need for an update was stated. This is taking place today.
- The recommended characterisation models prove to be applicable for specific study purposes when soundly interpreted. Application on a broad scale for the whole industrial sector, which is an ambition of EPD or PEF, is not possible as there is no room for interpretation in the declarations.
- There is not so much a lack of characterisation models, but a lack of relevant emission data and data to underpin the exposure terms.
- An incentive to provide LCI data for LCIA of toxicological impacts should be created.
- The use of REACH data should be further investigated.

The conclusion from the PEF meeting January 2015 "Current and future implementability of USEtox" [12] was: "In the context of the current activity of the PEF, USEtox must still be used for the screening and supportive studies, but it may not be used for benchmarking and communication purposes, until the outcome is more robust". The mid-term conference in Brussels November 2015 revealed problems with the application of USEtox in the pilot studies where toxicity was relevant.

EPD and PEF are information tools, supporting performance assessment of buildings or consumer products and thus are searching for tox-indicators which are:

- Independent of time and location and can be summed over the Life Cycle;
- Rank products‘ performances by toxicity potentials (intrinsic and exposure);
- Can be allocated to different modules of a building‘s Life Cycle;
- Are applicable to all construction products and make use of the official, publicly available database of REACH.

Starting from these conclusions BASF in Ludwigshafen started to investigate the possibility of using REACH data of intrinsic toxicity and exposure scenarios to describe a toxicity potential of substances relevant for the different life cycle stages of a product. The result was a draft of the methodology for ProScale, which was introduced to many stakeholders in a workshop in July 2015 in Brussels: "Toxicity performance assessment in sustainable construction" http://www.construction-products.eu/news-events/events/events/workshop-toxicity-performance-assessment-in-sustainable-construction.aspx. ProScale applies a hazard score, which is based on the derived no effect level (DNEL) of the substance under study and modifies it using its exposure scenarios either for the workplace or humans in the environment.

ProScale is a valuable supplement to LCA results. It describes the time and place independent

tocicity potential of substances or products when they are applied for building and using the building as well as the toxicity potential of the precursors of these substances in their production.
A life Cycle Indicator tells a completely different story. It describes the toxicity potential of an industrial system, which is put in movement for providing a certain product and its function. This includes ideally all emissions from raw material extraction to deposition in landfill independent of time and place.

2.4 Land use change

In the assessment of CEN TC 350 so far land use change is demonstrated to be relevant with respect to impacts on biodiversity, soil quality, availability of scarce resources and ecosystem functions. These issues are clearly relevant for buildings and/or construction products. JRC recommends a number of characterisation models for land use change and lately to further investigate the LANCA method. At the Institute für Bauphysik in Stuttgart and Fraunhofer Institut für Bauphysik a set of approaches to quantify land use implications of industrial processes have been developed [13]. They are based on the concept of land functions, and provides a framework and calculation instructions for different land use indicators. Of these, the approaches dealing with the indicators of erosion resistance, filtering and buffering and groundwater replenishment form the conceptual background for the calculation of land use change impacts in the LANCA® tool. It is discussed to combine the set of indicators into one indicator. A research project from the German Nature Conservation Agency also serves to improve the calculation of regionally specific biodiversity impacts of land use in LCA [14} applicable in the LANCA tool.

3. Implementing European harmonised EPD

The European standard EN 15804:2012+A1:2013 for EPD in construction was first publicly available as final draft in 2011, it was amended by specifying characterisation factors for LCIA in 2013 and today almost all POs have committed to apply the standard. Alone in Germany > 2000 datasets are publicly available for construction products. However, as expected, the practical implementation is still struggling.
In 2011 the eco-platform (www.eco-platform.org), an association of established and evolving EPD POs in Europe had its kick off. The objective of eco-platform is to support the implementation of European harmonised EPD, i.e. the development of verified environmental information of construction products through EPD according to the horizontal core PCR for EPD of construction products, EN 15804. The added value of EPD under the eco-platform framework is the possibility to use these declarations in all European and international markets. Manufacturers providing eco-platform EPDs to their customers will be able to optimise their investments avoiding additional fees, work repetition and reducing communication efforts.
The main achievement of the eco-platform until today is, next to providing a platform of exchange for its members, providing a common verification procedure for all members. The compliance with this procedure is audited. So far 9 of 14 members have passed the audit and have published180 so called “ECO EPD” These EPD are accepted and further distributed by all member POs in Europe. The EPD serve mainly for communicating the environmental performance of products by the respective manufacturers. In some of the existing building certification schemes EPD based data is applied for assessing the environmental performance of buildings: DGNB, BNB in Germany, HQE in France BREEAM in UK and other EU member states. LEED in USA also gives credits for providing information via EPD, Baubook in Austria
The application of the EPD information is still impeded by some technical hurdles. One is the diverging interpretation of EN 15804 by different POs. To support a uniform interpretation and also to support the PCR development for product TCs CEN TC 350 publishes a set of questions and answers (Q&A file) on its website. These refer to allocation issues with respect to flows leaving the

product system during production, construction and use and explicitly with respect to the declaration of flows in the correct modules - in particular in the end of life modules and module D. The latter provides additional information about recycling potentials for future uses and may not be added up to the product's system under study. It is clarified that cut off approach to end of life allocation is used, however supplemented by the module D information on future recycling. This approach allows the most reliable information with respect to the future. It does need interpretation as for energy dependent recycling the declared substitution benefits may be too optimistic. On building level evaluation, this information is nevertheless very valuable as some buildings can be seen as veritable future resource banks.

The explicit background to the Q&A file is given in a guidance document as technical report, WI 350020:2015, which is still in work, but can be expected in early 2016. It also includes guidance on the calculation and documentation of biogenic carbon. In detail this was also worked out by the product standard EN 16485:2014 "Round and sawn timber - Environmental Product Declarations - Product category rules for wood and wood-based products for use in construction" [15] by CEN TC 175. The eco-platform members are committed to using the guidance support as well as the PCR from product TCs.

Another hurdle is the different philosophies in the publicly available databases which give rise to relevant differences in those data sets that are needed to complete the LCA and are normally not known to the manufacturer (e.g. processes of raw material acquisition, end if life processes). DG Environment plans to set up a publicly available collection of data sets pre-verified according to the PEF guidance handbook [16]. Unless a better compliance between PEF and EPD is achieved, this will not be helpful for the implementation of EN 15804. On the other hand the commercial providers of – more comprehensive- databases like GABI and EcoInvent are also making efforts to provide pre-verified data sets for the construction sector based on EN 15804. The future will show which is faster and more comprehensive to serve the construction sector, which in fact in industrialised countries mobilises the complete industry system.

Different member states have set up databases of EPD information or equivalent LCA results from studies to support building assessment partly required through regulations. In Germany EPD are required for Federal buildings in order to assess the building performance – all buildings have to reach a level higher than plain regulatory requirements. In Netherlands a building permit is connected to building assessment, using EPD. In Austria financial incentives are connected to Baubook, which among other information uses EPD data. The requirements to enter these databases are not harmonised among the maintainers of the data collections. This is a task for the eco-platform already started. However the obstacle of different results from different databases is not solved.

In order to enhance the real life applicability the eco-platform members also developed a common format with respect to a common content and order of information, also applying the inversed tables recommended in EN 15942:2011 [17] Sustainability of construction works. Environmental product declarations - Communication format business-to-business".

The European commission is preparing an amendment to the original Mandate 350 for a European system of assessing the environmental performance of buildings. This amendment is to serve the alignment between EN 15804 and the PEF approach. While the EPD are in place for about a decade and the alignment with the horizontal PCR in EN 15804 was a success story which is now also carried over to the ISO level in the amendment of ISO 21930, PEF is still moving target for alignment! However it will be a blow to the voluntary investments of the construction sector in supplying the performance information for products, also vis à vis a possible use of this information in the construction products regulation, if there would be two different sets of requirements on the market. Achieving such an alignment will be necessary.

4. Conclusion and outlook

The information tool EPD based on EN 15804 is well accepted in the European construction sector. There are still obstacles in applying EPD uniformly throughout Europe. The eco-platform shows success in a common implementation of EN 15804 by providing a common verification procedure, common EPD format allowing EPD to be accepted by all members. The applicability of eco-platform EPD all throughout Europe is the goal for the next months. This will involve a common access to national databases and acceptance in all building rating tools.
The German federal agency for construction and urban development (BBSR) co-operates with a group of European data providers (EPD program operators and scientific institutions) to enlarge the Ökobau.dat database by developing common data quality criteria and verification rules for access to this database. The incentive to enter is due to its automatic link to the German building rating tools. This project is also on the ECO platform's screen, where very detailed, consensus based verification rules already exist. It is in the ECO platform's interest that all ECO-Platform-EPD from any member program operator should have access to such databases.
A further step by the ECO Platform is to use the recently finalised FPr16970, the guidance document for the implementation of EN 15804 to minimise technically different interpretations of the European standard.

A challenge is also the alignment between EN 15804 and the PEF approach. An amendment of EN 15804 to include new indicators and clarify some interpretation issues is very probably to be introduced by an amendment of the M350 for CEN TC 350 [18]. The content is still controversial but should serve the alignment of the PEF approach with EN 15804.
Hidden in this development is a chance for the European standardisation process to improve the building assessment system e.g. by enlarging its scope with additional indicators. The performance concept, part of the standard system for building assessment and applied in certification schemes, allows planners to decide by themselves how to achieve highest rating instead of defining the path through measures. LCA based indicators seem to guarantee such a performance approach. However the question needs to be allowed if LCA is the only methodology to achieve a performance approach. LCA allows the aggregation of quantified impacts across time and place as a basis for the performance approach. This in turn prevents risk assessment. The discussion about which environmental or social aspects considered in building certification schemes should be dealt with via risk assessment, and which should be answered by describing the impact potential is still open. Just as examples: where inhabitants would like to be informed about how the building they live in interacts with their health, risk based information seems appropriate. Where society should be informed about potential impacts on biodiversity connected to the supply chains of construction products an LCA based indicator could be more adequate.
The enlargement of the scope of the core EPD according to EN 15804 is a typical hen-egg dilemma. If there is not enough data, indicators cannot be served. Without the incentive of applied indicators, data will not be provided. A stepwise opening of the scope could be the answer: voluntary information through new indicators, interpreted for each declaration could be a starting point. Once enough experience is collected, the new scope can become mandatory.
Another major issue still is the difference in the background databases. The European commission is planning to license generic datasets for the most important and more remote upstream and downstream processes to generate PEF declarations, interlinked with a requirement to use specific data farther up- and downstream than the actual control of the manufacturer over processes reaches. Questions on data quality management will have to be answered as well as on stability of conventions about necessary assumptions. In the meantime private databases update their data, but there are still differences in the philosophies originating not the least from different goals and audiences for which the database is designed. Without an alignment between the EPD and PEF system these remedies are quite futile.

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European LCA data network – open public online database and data format of ÖKOBAUDAT as a starting point?

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Summary

Sustainability considerations in the construction sector are established in many European states, many of them are using certification schemes to evaluate sustainability at building level. Within these, the life cycle assessment (LCA) at building level is a central instrument for the evaluation of the ecological quality of the building, i.e. environmental impacts causing global warming, ozone hole, smog, acidification and eutrophication.
The basic material data for such LCA are given in environmental product declarations (EPD). Nowadays, a rising numer of EPDs is produced. As building products are used within the European, and global, market, there is an interest in using EPD data from products of other states in an open way.
In the paper an open LCA data network structure with a common standard data format is presented, which allows open access to EPD data from all participating databases. The idea is to not to establish anything as a new (background) database but to offer a format and a structure which allows to commonly share existing (or in future created) EPD data (following EN 15084) which are based on whatever background database (e.g. GaBi, ecoinvent, others). A harmonized format and the possibility of online access and exchange of data between EPD databases from different nations will hopefully support harmonization of LCA processes for sustainable building. There already has been developed an infrastructure for an online database situation with tools and interfaces for data exchange. This system, as established within the German Assessment System for Sustainable Building (BNB) for Federal Buildings, which is following European and International Standards, offers a good starting point for the establishment of an open international data network for LCA databases.

Keywords: life cycle assessment (LCA), sustainable buildings, data exchange, building assessment system, building products, environmental product

1. Introduction

There are numerous political initiatives - at global, European and national levels - that formulate political objectives in connection with sustainability, such as energy efficiency, resource efficiency, and reduction of greenhouse gases. As a consequence, sustainability considerations in the construction sector are established in many countries, often using certification schemes to evaluate the sustainability of buildings. Well-known systems are e.g. Environmental Assessment Method

(EAM) by Building Research Establishment (BRE) BREEAM (UK); Leadership in Energy and Environmental Design LEED (USA); German Assessment System for Sustainable Building for Federal Buildings (BNB) and German Sustainable Building Certificate (DGNB) (Germany); Minergie (Switzerland); High Quality Environmental standard HQE (France); Comprehensive Assessment System for Building Environmental Efficiency CASBEE (Japan, Asia); and their regionally adapted modifications.
Usually, within certification schemes of sustainable building LCA is a central instrument to calculate the ecological impact of a building, that means to determine the potential of global warming, ozone depletion, photochemical ozone creation, acidification, and eutrophication, and further environmental indicators. The basic material data required for these LCA calculations are provided in EPD produced by building products manufacturers or relevant associations within the framework of EPD programs.

Only since European Standard EN 15804 [1] was written to introduce more rigorous rules for the building sector in how to set up the environmental models of the life cycle products and calculate comparable environmental life cycle indicators, more EPD programme holders implemented EN 15804 into their specific programs. Thus, in many European or other states a rising number of EPD is produced conform to EN 15804. As products are used within the European or global market, it is to emphasise, that there is an interest to use data from any other EPD program operator, for LCA at building level.
So far, some states are just about to get started with databases for LCA data (from EPD), usually at a national level. To avoid the development of a great variety of databases with the danger of incompatibility of data, the idea is the initiation of an open European or International LCA data network structure for sustainable building with a common standard for the data format (Fig. 1).

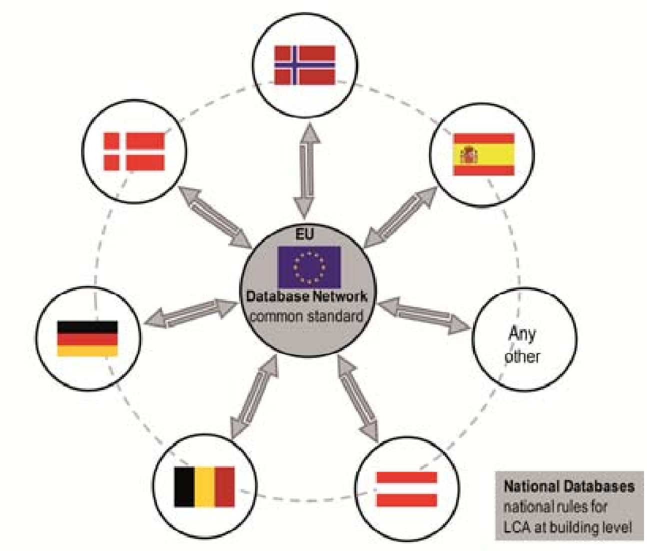

Fig. 1 Scheme – open international LCA database network for sustainable building

2. BNB – German approach for LCA via open data network

In Germany, as part of the Assessment System for Sustainable Building (BNB), the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), provides important infrastructure for choosing suitable building products. There is offered a “tool chain” (Fig. 2). It starts with the basic material data from environmental product declarations (EPD), which are imported in the online database ÖKOBAUDAT, exported from there to the calculation tool "eLCA", and finally, are used for the final evaluation of a sustainable building resulting in a bronze, silver, or gold BNB-certificate. All provided tools are web-based, cost free and publicly available.

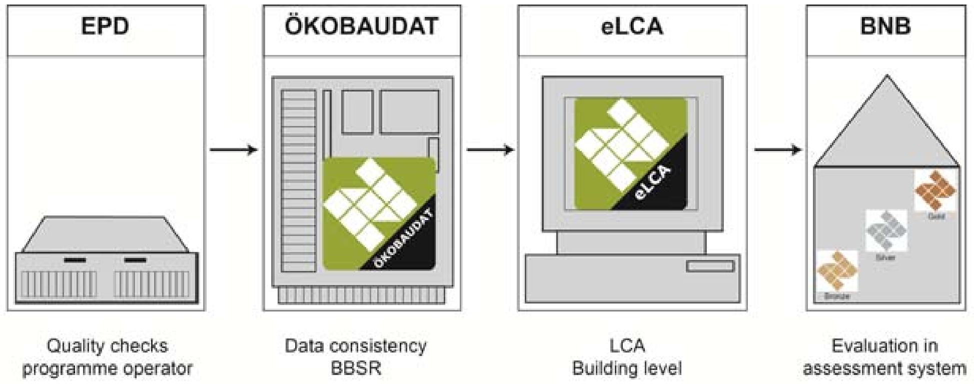

Fig. 2 Infrastructure BNB – from product data via LCA to final evaluation of sustainable buildings

2.1 ÖKOBAUDAT

The German online database ÖKOBAUDAT is provided by BMUB already since 2009, and it is available for everybody interested in an ecological evaluation of building with a consistent database. Main users are planners and architects, who analyse the environmental indicators of the products, services and processes as integrated in the database.

2.1.1 Webpage

The webpage (www.oekobaudat.de) offers a user friendly direct access to the database. Also, basis information, as well as interesting links, is given. Different versions of the ÖKOBAUDAT are archived. This can be relevant for ongoing projects as well as for reproducing former LCA results. Search- and filter-functionalities allow finding relevant datasheets for chosen materials or products directly in the online database. A comprehensive English version of ÖKOBAUDAT is provided since June 2015.

ÖKOBAUDAT contains generic basic datasets that provide suitable averages of the environmental indicators for the building materials, as well as product-specific datasets that are determined within EPD. Using the generic datasets allows sustainability studies of buildings already in early planning stages when architects or planners do not yet work with product specific but with generic building product information. In a later stage, the generic data in the model are then substituted by specific data representing actual construction products.

2.1.2 European Standard EN 15804 [1]

Since 2013, ÖKOBAUDAT comprehensively meets the demands of EN 15804. The data had to be adapted to life cycle modules, and abiotic resource depletion potential (ADP) was integrated as a new indicator. The datasheets of the ÖKOBAUDAT furthermore include information on the raw materials production and production processes used in the manufacture of the product, e. g. cradle-to-gate.

The German Institute for Construction and Environment e.V. (IBU), which significantly contributes product specific data sets for the ÖKOBAUDAT, was the first to introduce EN 15804 in its EPD program rules. Other EPD programs followed.

2.1.3 Data format

The data format of ÖKOBAUDAT datasets fully meets the requirements of EN 15804, but also follows an extended International Reference Life Cycle Data System (ILCD) format. It has explicitly been designed to allow publishing and linking of data as resources via internet.
The advantage of this new approach is that existing software tools with built-in support for the ILCD-format can be easily enabled to support the new EPD datasets as well, with only minor changes to their internal information structures. It is to emphasise that ÖKOBAUDAT is running on an open source program software platform (soda4LCA), which allows the development of further modules which use or may add new features to the procedures.
The possibility to directly import data into an online database or platform, (this could be a European/International joint database, or a European/International data network) with a given harmonised data format which follows the generally accepted European/International standards is a great chance for the idea of a consistent and comparable establishment of LCA within the context of sustainability considerations in the construction field.
The Life Cycle Data Network (LCDN) initiated by the European Commission is aiming at providing consistent and quality assured LCA data and contains life cycle inventory (LCI) and life cycle impact assessment (LCIA) data in a wide range of applications. It is currently gaining a lot of traction as more organisations choose to publish their data. The focus is more on data that can be used for LCA studies rather than EPD. This sets a good example of how data adhering to certain quality criteria can be published by individual parties and yet at the same time be conveniently available to a large user base.
As the proposed approach is based on the same technical infrastructure, data format and protocols as the LCDN and thus it could even potentially become part of the LCDN in the long run.

2.1.4 Data transfer

Since 2014 ÖKOBAUDAT is presented as online database. Decisive is the provision of interfaces (API interface) which allows direct online import of LCA data to the database ÖKOBAUDAT. There are two possible ways: a) direct EPD data import via interface, and b) data transfer via LCA tool “openLCA” (Fig. 3).

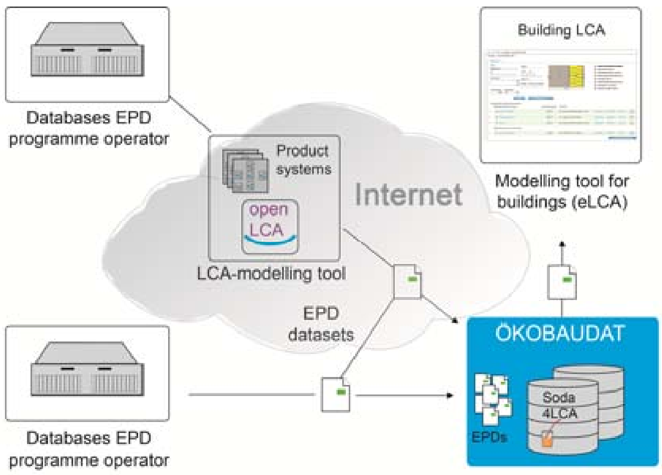

Fig. 3 LCA data import into and export from ÖKOBAUDAT

In Germany, the Institute for Construction and Environment (IBU) as an important EPD program operator has equipped its own database application with facilities to directly import its data online into ÖKOBAUDAT. As not all institutions which may offer suitable building materials related data will be able to generate data with an tool of their own, a further research project had been set up to modify the widely-adopted open source LCA modelling tool “openLCA” accordingly to allow creating suitable LCA data which subsequently can be imported into ÖKOBAUDAT, even online directly from openLCA [2]. This indirect data transfer is currently carried out by German EPD program operator ift Rosenheim, and Austrian EPD program operator Bau-EPD, as well as by German Thünen Institute for its averaged LCA data derived from industrial background data for wooden materials. All these newly imported data were released in ÖKOBAUDAT in summer 2015.

The input procedures ensure that every data sheet is structured in the same way (dataset) (Fig. 4). This allows for a high level of harmonisation and data consistency, which is an important precondition for data export in LCA tools like eLCA, commercially available tools, or even excel tools.

Indicators of the impact assessment

Indicator	Unit	Production	Construction-installation process	Waste processing	Disposal	Reuse- Recovery-Recycling-potential
		A1 - A3	A5	C3	C4	D
Abiotic depletion potential for non fossil resources (ADPE)	kg Sb-Equiv.	0.0009389	4.67E-09	5.21E-10	2.13E-07	-1.37E-07
Eutrophication potential (EP)	kg Phosphate-Equiv.	0.005367	0.00001067	0.000001133	0.0006611	-0.001
Abiotic depletion potential for fossil recources (ADPF)	MJ	313	0.1444	0.01111	7.978	-42.21
Acidification potential of soil and water (AP)	kg SO2-Equiv.	0.03972	0.000054444	0.000005356	0.003667	-0.01228
Global warming potential (GWP)	kg SO2-Equiv.	21.26	0.5056	0.1	2.994	-3.5
Depletion potential of the stratospheric ozone layer (ODP)	kg CFC 11-Equiv.	2.84E-08	3.69E-11	2.1E-12	5.4E-10	6.83E-12
Formation potential of tropospheric ozone (POCP)	kg Ethene-Equiv.	0.004867	0.000003406	6.33E-07	0.001044	-0.001839

Fig. 4 Detail of data sheet with life cycle modules according to EN 15804

All data transfer procedures are administrated by BMUB/BBSR (Federal Institute for Research on Building, Urban Affairs and Spatial Development), which always checks the adherence to the “requirements for the acceptance of LCA data in ÖKOBAUDAT” (published on the webpage), e. g. the compatibility with EN 15804, EPD program rules, verification of data by an independent third party, period of validity of data, data format and some additional requirements for ÖKOBAUDAT. All data are imported to an “inbox”, where they are quality checked for plausibility and completeness before being released in ÖKOBAUDAT.

2.2 eLCA

However, ÖKOBAUDAT delivers LCA data of building products that are factored into the LCA at building level. Consequently, a further BMUB research project was initiated with main purpose to develop a BNB compliant LCA tool for buildings. “eLCA” is an open source online tool, available since January 2015 (www.bauteileditor.de). It is user friendly and allows for a consistent and comparable LCA at building level. Motivation for the development of “eLCA” was to adapt an LCA tool to the needs of BNB. Furthermore, the tool can be used for the derivation of benchmarks, and it allows adapting the tool to any required changes with a high level of independency.
Within “eLCA” the building structure is created by the components and construction elements with the associated materials. The underlying data of materials is given in the ÖKOBAUDAT – in “eLCA” the contribution of all materials to the environment has to be calculated in the amount of

the materials as used in the real construction, according to German Standard DIN 276 [3]. A specific feature is that the creation of elements is associated with dynamic graphs which show the thickness of different material layers – this helps to prove the created building components and elements (Fig. 5).

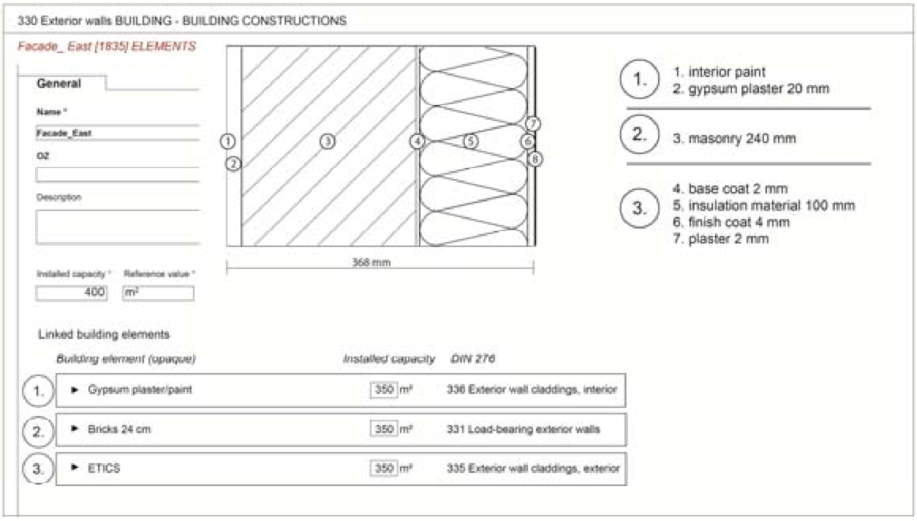

Fig. 5 “eLCA” – dynamic visualisation of input-parameters and building elements

The product and construction stage, use stage, and end of life stage are considered within “eLCA”. The evaluation of the project's LCA can be presented as a total score result, which is relevant for the evaluation of the addressed sustainability criteria within BNB, but also separated into construction elements (cost groups according to German Standard DIN 276) or relative to the life cycle stages (Fig. 6).

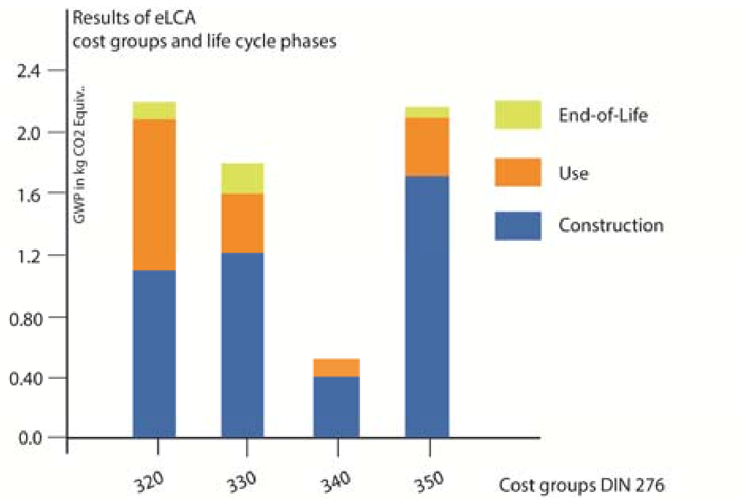

Fig. 6 eLCA – graphic results of GWP in cost groups and life cycle stages according to DIN 276 [3]

With ”eLCA” the calculation of new constructions and refurbishments is possible. It is used for evaluation of different sustainability criteria within BNB. As the choice of construction and products may have a significant influence on these ecological results within BNB, “eLCA” is used in the different planning stages. Nowadays, “eLCA” is used by many engineering offices as well as by up to 35 universities. An English version of “eLCA” is planned for 2016.

3. LCA – a European approach

The possibility to directly import data into a joint online database, or linking databases, with a given harmonised data format which follows the generally accepted European standards, is a great chance for the idea of a consistent and harmonised way of using material and product relevant LCA data, or EPD data respectively, for LCA at building level internationally. The idea behind the described developments is the vision of an open data network where independent national databases are linked to each other with open search and use of data with a common data format. Anyhow, each state will have the opportunity to set up own national rules for the use of data in subsequently used LCA tools, or other processes.

Fig. 7 shows the already established (or planned) international co-operations with data transfer between national databases and German ÖKOBAUDAT: transfer of data into ÖKOBAUDAT (Austria), external use of ÖKOBAUDAT (Denmark), and the planned linking of the Spanish database “opendap” with ÖKOBAUDAT.

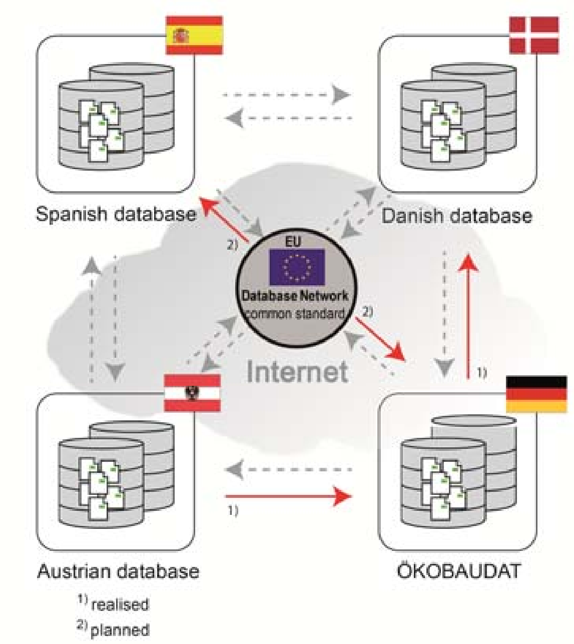

Fig. 7 Current (international) use of (online) LCA infrastructure / ÖKOBAUDAT

These co-operations are a good starting point for further developments, especially as already other international stakeholders are highly interested in using the developed data format and finding a way of linking databases. There are important aspects, which still need to be discussed, and analysed in further projects. For example, harmonisation of background databases, harmonisation or mapping of different product category structures, development of common minimum standard of required information, determination of levels of data quality, administration and help desk etc.

4. Discussion

An important aspect is to guarantee a qualitative assessment of data for the users. The origin of a dataset, as well as the background database used (for example, GaBi, or ecoinvent), has to be known.

The knowledge about the background database, which has been used for calculation, is important as the final LCA results may differ significantly depending on these background data. These differences in LCA results are a currently existing, and show a lack of harmonisation of background databases. Due to the differences in LCA results, most states show a preference for one or the other of the existing background databases.

In Germany, ÖKOBAUDAT has focused on the background database GaBi (or equivalent). Within the German assessment systems this specification is considered sensible for reasons of data consistency and comparability, as demanded according to EN ISO 14025 [4]. Anyhow, as there is and should be a free choice in the use of background databases for EPD, it was decided to open up the ÖKOBAUDAT platform. Fig. 8 shows the intended systematic. The online database platform ÖKOBAUDAT can store EPD datasets of different background databases. At the moment this is realised for background databases GaBi, and ecoinvent. Some EPD data sets based on ecoinvent as background database already have been imported to the online database (inbox). With appropriate filters, it will be possible to find these datasets. Nonetheless, rules about the use of these data within eLCA and BNB still have to be established. Probably, the use of less or non-consistent data will be restricted to those cases where the current ÖKOBAUDAT cannot provide appropriate datasets. Anyhow, the technical basis for the implementation of different filters, like information on background database, validity of data, etc. is given by the underlying database system soda4LCA.

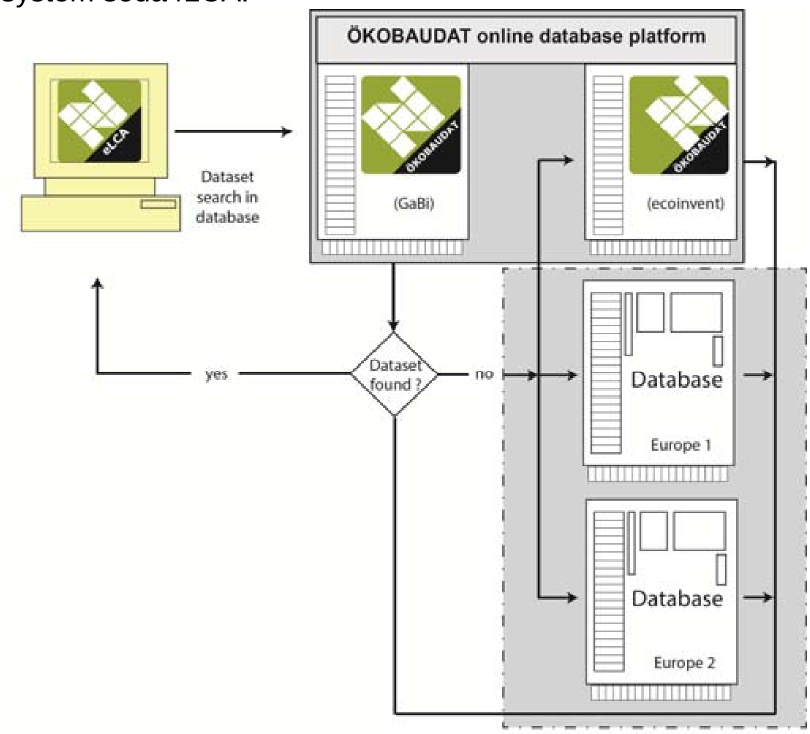

Fig. 8 Possible use of data in LCA tools within an open LCA database network

The described developments of the new data format and organisation in an online data system are in the phase of initial application. Hence, the ongoing and planned projects for data exchange (at the moment with ÖKOBAUDAT) are a good starting point for further developments. The described co-operations already show not only the vision but also the practicability of an open data network for LCA within sustainable building as well as a variety of unsolved aspects.

Anyhow, there is a high potential for a harmonised and consistent way of using material- and product-relevant LCA or EPD data for the LCA of buildings. For this reason, in March 2015 a working group “International open Data-Network for Sustainable Building (InData)” was founded (Austria, Belgium, Denmark, Germany, Norway, and Spain). The initiation of a European research project, and bi-lateral co-operations, is contemplated, in order to bring forward the idea of an open data network for a broader use of LCA data in a harmonised and consistent way.

The main idea is to develop and offer the structure for an open data network (Fig. 1), but, as indicated, there are several aspects, which have not been harmonised within standards yet, and hence, need still to be discussed and require development of concepts within joint activities.
Delivered data should follow EN 15804 and it is not the aim to set up new, or other rules, but of course some interpretations and common agreements will become necessary. Also, current developments, such as PEF, or establishing new indicators for health or biodiversity within EN 15804 will have to be observed carefully. The proposed data format can be adapted to changes and e. g. implement new indicators easily. Still the following aspects will need careful analysation and common agreements.

- *Background databases*
  The use of different background databases for LCA calculations may lead to significantly differing results for the considered environmental indicators. Hence, one objective is the harmonisation of background databases. For the current situation, also, concepts for transparency of data quality and for the use of data from different backgrounds will have to be developed. This complies research in order to analyse differences in data and allocations approaches.

- *Structure of building products in data bases*
  Program operators already have established several structures for product categories within their programs or database systems. There is the need for a common approach of structuring or mapping existing structures. Concepts are required which implement suitable search and filter functions to find appropriate data from other databases. Also, different languages and translations to English, which will be the common language, have to be dealt with. Anyhow, an advantage of the underlying data system soda4LCA is the built-in multi-lingual support. That is, that the input mask can be given in any wished language and only input texts need further translations.

- *Common standard*
  For an open data network a common minimum standard and precise definitions of required and additional information will be the basis for an exchange of data. Probably, it will be helpful to categorise and define different levels of data quality. A high transparency of data information (such as origin of data, validity of data, etc.) will support a sensible use of data in subsequent LCA calculations.

- *Technical development and applications*
  An open data network needs commitment to a common technical basis (programs, interfaces etc.). Such a system needs to offer compatibility with subsequent applications and tools such as LCA tools, building information modelling (BIM), and others. Furthermore, a corporate design might be an aspect. Also, rather organisational aspects like hosting, responsibilities, ownership of data, and administration need suitable concepts. The whole system needs to be adaptable to changes in the LCA world. Standardisation, for example, is an ongoing process and changes like the introduction of new indicators might occur. Also, ISO standards or European discussion about the product environmental footprint (PEF) may lead to changes in the LCA approaches for building products and sustainable building considerations.

5. Conclusions

In the paper, the idea of an open data network for the use of LCA data for sustainable building is proposed. In the building sector, the number of EPD produced according to European Standard EN 15804 is growing, and databases for collecting and structuring EPD data are about being established. As building products are used within the global market, there is a high need and

interest in harmonisation of LCA methods and consistency of background data, and data format. A suitable LCA infrastructure already has been established and is being used in Germany within BNB. EPD data are imported in a database (ÖKOBAUDAT), which is subsequently used by LCA tools at building level (eLCA). All used programs and tools are open source and publicly available, which supports the idea of an open and transparent exchange of data. These structures are considered as a good basis and a starting point for joint international activities: the data format is compatible with EN 15804 as well as ILCD format; multi-language support is built in; open source and systematic of underlying soda4LCA allow for further development and adaptions required for an open network with many stakeholders; suitable interfaces allow online data import and export to other tools and systems. Furthermore, some initiatives were already started to bring forward the idea of a harmonised LCA data exchange. The challenge is, to get started with joint activities and to develop concepts which meet the demands of various stakeholders. A common standard will have to be found which leaves possibilities for additional national information. The overall goal of a harmonisation and a sensible use of data will require a high transparency of data and background information, also, the determination of different level of data quality. Furthermore, a common basis regarding the technical framework is required, e.g. software, interfaces, hosting.
Furthermore, the idea of an open data network would support European ideas. In order to bring forward this idea, in general, political programs and support is very helpful, also for the definition of responsibilities. It is very helpful to run one central national database for EPD data rather than having different databases by several program operators. Experience in Germany has shown that the centrally bundled provision of data and tools by the government is a highly supportive instrument for a wide application of LCA at building level and the realisation of sustainable buildings.

6. Acknowledgement

The projects described in the paper were funded by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) within the framework of the research program “Zukunft Bau”. The authors are grateful to all involved researchers.

7. References

[1] European Standard EN 15804 - Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.

[2] DÜPMEIER, C., KUSCHE, O., BROCKMANN, T., RÖSSIG, S., CIROTH, A., & LODE, T., *„Towards a complete tool chain for eco-balancing governmental buildings.”* Proceedings of the 28th EnviroInfo 2014 International Conference on Informatics for Environmental Protection: ICT for Energy Efficiency, September 10-12, 2014, Oldenburg, Germany, pages 173-180.

[3] German Standard DIN 276 – Costs in construction sector („Kosten im Bauwesen“).

[4] EN ISO 14025 – Environmental labels and declarations – Type III environmental declarations, principles and procedures (ISO 14025).

8. Links

www.nachhaltigesbauen.de (some English information)

www.oekobaudat.de/en (full English version)

www.wecobis.de (health relevant and environmental aspects of building materials; only German)

www.bauteileditor.de (eLCA tool; so far, only German, English version planned 2016)

www.openlca.org

www.opendap.es

Evaluation of green roof hydrologic performance for rainwater run-off management in Hamburg

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Summary

Adaptation to the unpreventable consequences of climate change is one of the main challenges for cities in the coming decades. Especially for urban areas, where consequences of climate change will occur concentrated, there is a need for sustainable climate change adaptation measures. Our research focusses on one example of adaptation measures: green roofs. In addition to long-term economic benefits, they offer a wide range of benefits for urban ecosystems. Besides thermal benefits, like reduction of heating and cooling costs and reduction of the urban heat island effect, green roofs improve the urban water cycle, reduce air pollution, and enhance biodiversity. In Hamburg, heavy precipitation events regularly lead to overwhelmed urban drainage systems. Such events are expected to occur more often in the future with increasingly frequent (and intense) extreme precipitation events. Therefore, rainfall-runoff measurements of an extensive green roof on the HafenCity University building are carried out to determine the water retention capacity of the roof and to estimate the potential retention during heavy precipitation events. The long-term results show rainfall-runoff relationships under various weather conditions and are important for the development of future water management strategies and to overcome doubts about the effectiveness of green roof water retention, especially related to extreme precipitation events.

Keywords: green roof; climate change adaptation; water management; extreme precipitation

1. Introduction

There are several types of modern green roofs, consisting of the same principal elements: a waterproofing membrane covered with a growing medium and vegetation, which are installed on a rooftop. Other commonly used elements include root barriers and drainage layers (see Fig.1). In addition, filter layers are often integrated into the system between the substrate and drainage layer to avoid washing out of small-sized particulates. While the root barrier protects the waterproofing of the roof from penetration by plant roots, the drainage layers should be both able to retain rainwater and drain away the surplus water. Drainage layers can be industrially produced plastic frames as well as gravel layers. The substrate layer functions as growing medium for plants, by providing a rooting zone, and as water storage medium. It is typically a light-weight aggregate with both high water holding capacity due to high porosity, as well as good drainage properties. Substrate depth is an important property controlling water retention capacity, plant groth and subsequently, plant selection. Depending on substrate layer thickness or plant root-penetrable depth of the medium, two types of green roofs are distinguished. Extensive green roofs have a thicknesses of 8 to about 15 cm and intensive green roofs >15 cm. The types of plants used depend on the type of green roof and local climate. On extensive green roofs, due to regular drought stress, winter-hard, drought-tolerant and perennial plants like sedum species dominate. On intensive green roofs, grasses, shrubs and even trees can grow.

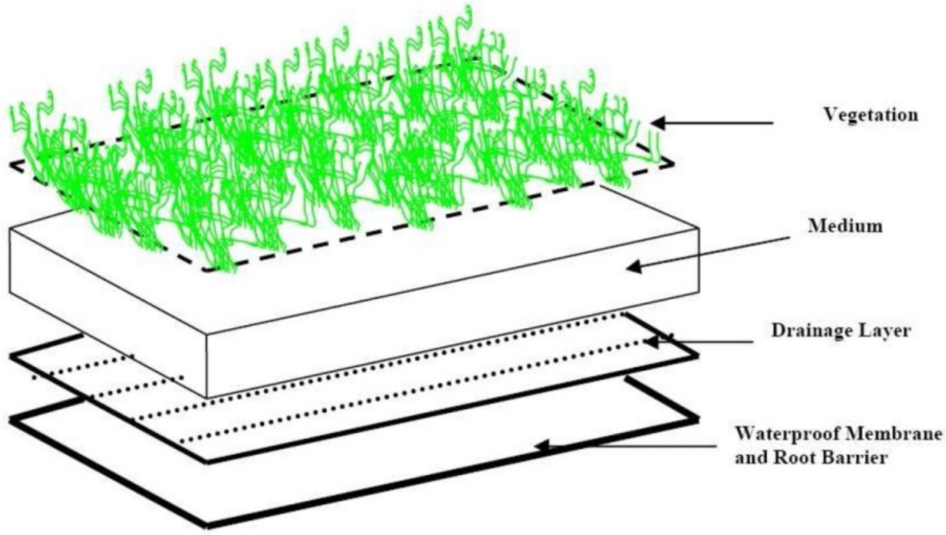

Fig. 1 Typical cross-section of a green roof system [1]

Several environmental and economic benefits are attributed to roof greening. Green roofs' installation costs are higher than those of standard flat or gravel roofs with 15 to 50 €/m² for extensive green roofs and from 50 €/m² upward for intensive green roofs, compared to about 10 €/m² for gravel roofs. In the long term, higher installation costs often pay off due to decreased sewage fees for utilised rainwater, lower repair costs due to higher durability (about 50 years) compared to conventional roofs (about 25 years) and energy savings. Furthermore, several cities like Hamburg promote green roofs with financial funding programmes to support widespread establishment. Further benefits are the reduction and attenuation of stormwater runoff due to water storage in the medium and on the plant surface, slow realease of rainwater out of the medium, transiration of plants and evaporation from substrate and plant surfaces. These lower the risks of urban floods and improve the urban water balance to approach a more natural condition (e.g. [2], [3], [4]). By thermally insulating and shading the roof surfaces and cooling through evapotraspiration, roof greening can reduce the costs of heating and air conditioning and the magnitude of the urban heat island effect (f.e. [5], [6], [7]). Green roofs also reduce noise levels (investigated numerically by [8]), reduce air pollution by filtering ([9], [10]) and provide wildlife habitats and enhance biodiversity ([11], [12], [13]).

The focus of this study, nevertheless, lies on the effectiveness of green roofs for urban rainwater management. Several studies regarding rainwater runoff retention state that the rate of rainwater retention for certain rainstorms depends on roof slope [14], substrate depth [4], rainfall characteristics like duration and intensity [15], season [16], soil moisture [17], roof age [18], plant species [12] and growing media type [19]. It is clear that over a whole year, green roofs with a substrate layer thickness of more than 6 cm can retain about 50% of precipitation and intensive green roofs with growing medium thickness >50 cm can retain up to >90% [20]. For urban rainwater management and especially dimensioning of sewage systems and prevention of flash floods due to sewage overflow, the retention capacity of green roofs in case of local extreme precipitation events is of interest. It is still not clear whether comprehensive implementation of green roofs can significantly affect rainwater retention and runoff reduction or delay the heavy rainfall events that cause flooding due to overcharged sewer systems. This problem is tackled by a comprehensive systematic review of literature on green roofs and water retention and a rainfall-discharge-measurement approach on the green roof of the HafenCity University (HCU) building.

2. Methodology

2.1. Systematic review

To get an overview of the published research regarding green roofs and their possible effects on rainwater management, a systematic review methodology, decribed in detail in [21], was applied. The overall research question "How effective are green roofs in reducing runoff into sewer system from heavy precipitation events?" was thus split up into the four main elements of the systematic review:

1. Population of interest or what problem is being addressed? (Green roofs)
2. Type of intervention or exposure? (Precipitation/runoff events)
3. What is the comparison/ comparator? ("conventional roofs")
4. What is the outcome or endpoint? (reducing and/or shifting runoff peak)

With these four elements (and synonyms), 9 different scientific databases from the fields of geo-sciences, environmental sciences and nature onservation, technics, architectural and urban studies were searched systematically. In this way, 70 studies were selected for the purposes of this study, of which the greatest number of studies originated from the USA (23), Germany (15), Canada (5), the United Kindom (4), Sweden (3) and Italy (3). Following, the results of the studies were entered into a database including the following features: Author(s), Location/Country, Latitude, Year(s), Experimental set-up, Size [m²], substrate depth [mm], drainage type, planted/non-planted, substrate, slope [%], Precipitation type, Yearly/period of study Precipitation, Yearly/study period retention, Winter retention, Summer retention, Rainstorm intensity [mm], Rainfall duration [min], Peak discharge coefficient, Volumetric retention, Runoff initiation [min], Peak delay [min], Initial conditions, Antecedent dry weather period [h], Water storage [mm]. Some refer to the overall water retention over a period (f.e. season or year) and some refer to single precipitation events. Thus, not all studies could provide data for all fields. With these data, water management related factors were analyzed and statistically tested to recognize significant dependencies between different factors.

2.2. Rainfall and runoff measurement system at HafenCity University building

The green roof of the HCU building is an extensive green roof vegetated predominantly with *sedum* and *phedismus* species (see Fig. 2). The substrate layer with 6 cm thickess is made of clay tiles mixed with organic compounds. The drainage layer (high-density-ployethylene, 2 cm thickness) is combined with an overlying filter layer. The green roof has a size of about 2200 m², of which about 600 m² of the roof drain into the measurement system.

Precipitation on the roof and runoff from the roof are measured separately. A Lambrecht rain gauge including a tipping counter with a resolution of 0.1 mm is situated at the North-eastern part of the building. Runoff from the roof is drained from 3 roof outlets into a measurement box on the ground floor of the building. In this box (Fig. 3), 2 different discharge measurement systems are integrated. A tipping counter with 100 ml resolution records smaller discharges whereas an ultrasonic sensor records higher discharges (up to 60 l/s) via water level measurement in a Thompson-weir outlet. The measurement system was installed in March 2015 and has been recording Rainfall and runoff since then in a temporal resolution of 1 minute.

Fig. 2 View over the HCU green roof

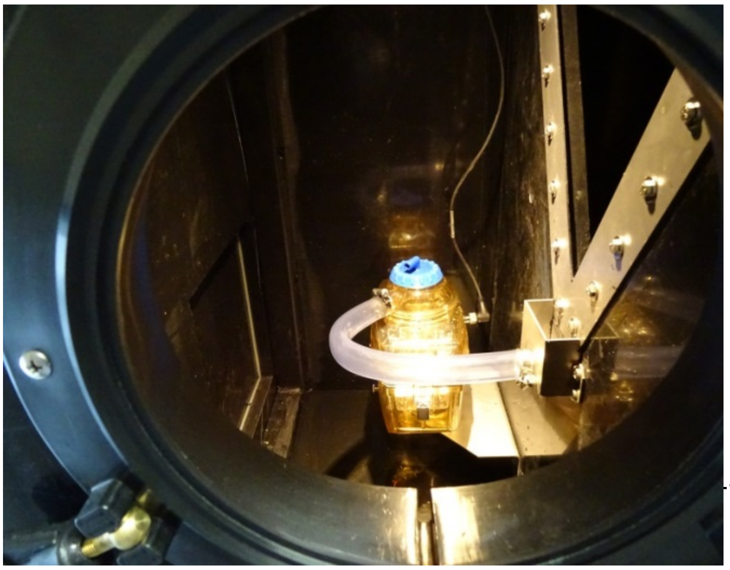

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Fig. 3 View inside the runoff measurement box with V-weir (right) and tipping counter (middle)

3. Results

3.1 Systematic review

The systematic review results indicate a wide variety of properties characteristic of rainwater management (Tab. 1). Over all studies, the average yearly (or whole study period) water retention was 56%, ranging from 12% to 90% for an intensive green roof in sub-mediterranian Trieste, Italy [22]. The periodic retention rates differ within colder and warmer periods; average winter retention was 36% (12-69%) and summer retention 72% (32-100%). For single precipitation events investigated in the studies the average water retention of green roofs was 57%, ranging from zero retention to 100%. The average peak discharge coefficient, meaning the ratio of peak rainfall intensity [mm/min] to peak roof runoff [mm/min], was 0.4 (range: 0-1). The duration till runoff initiation from the green roof and peak delay from rainfall peak intensity to runoff peak intensity were delayed for 277 minutes (-8 – 2290 minutes) and 192 minutes (0 – 2000 minutes) on average.

Tab. 1 Rainwater and runoff related effects derived from systematic review

	Average	Maximum	Minimum
Year/study period average retention [%]	56	90	12
Winter retention [%]	36	69	12
Summer retention [%]	72	100	32
Volumetric retention rain event [%]	57	100	0
peak discharge coef-ficient	0.4	1	0
Runoff initiation [min]	277	2290	-8
Peak delay [min]	192	2000	0

Pearson-Correlation tests with data from the reviewed studies showed that runoff-retention describing factors (average retention, seasonal retention, retention single rain event, peak discharge coefficient, runoff initiation and peak delay) were significantly correlated ($p<0.05$) with the thickness of soil substrate (the thicker the layer the more retention), the soil moisture before the rain event (moister soil leads to less retention), the precipitation intensity and duration (higher intensity and duration leads to less retention), the roof slope (more slope, less retention), the season (more retention in warmer months) and latitude (less retention with higher latitude). No significant correlations could be proved with vegetation cover, plant species composition, growing media type and roof age.

3.2 Rainfall and runoff measurement system at HafenCity University building

Rainfall and runoff measurements on the HCU green roof were carried out starting at the end of March 2015 in 1-min temporal resolution. The results for longer periods and single rainfall events are described separately in the following sections.

3.2.1 Long-term green roof retention

During the period of study presented here (23.03.-10.12.2015) 668 mm precipitation were recorded whereof 277 mm were discharged. This means 59% of the rainfall was retained by the green roof (Tab. 2). As can also be seen in Tab. 2, June is the month with the most retention (74%) while the least (29%) water was retained during the first 10 days of December.

Tab. 2. Precipitation, discharge and retention measured at HCU green roof from 23.03.-10.12.2015. *indicates that the data are not for the whole month.

Month/period	Precipitation [mm]	Discharge [mm]	Retention [%]
March*	42	19	53
April	38	14	63
May	45	14	70
June	39	10	74
July	107	34	68
August	105	37	65
September	89	39	66
October	41	20	51
November	155	84	46
December*	7	5	29
Whole period	668	277	59

3.2.2 Single precipitation events' retention

Over the measurement period, several heavy precipitation events occurred in Hamburg. For urban stormwater management, the retention potential of local short-term events is especially interesting. During the study period 2 short events were recorded and evaluated (see Fig. 4). On may 5th 2015, 17 mm of precipitation in 60 minutes were recorded. During 5 minutes the measurement range of the rain gauge was exceeded, thus we assumed the maximum possible measurable precipitation amount for these minutes (1,8 mm/min). The recorded event corresponds to a return period of 1.7 years for Hamburg. In reality, this rain event was heavier than recorded. 8 mm of roof runoff was recorded, which corresponds to 53% retention. The peak discharge coefficient was 0.5. Another heavy precipitation event with 18 mm in 105 minutes was recorded on August 17th 2015 (return period for Hamburg: 2 years). Here, 50% was retained and the peak discharge coefficient was 0.25.

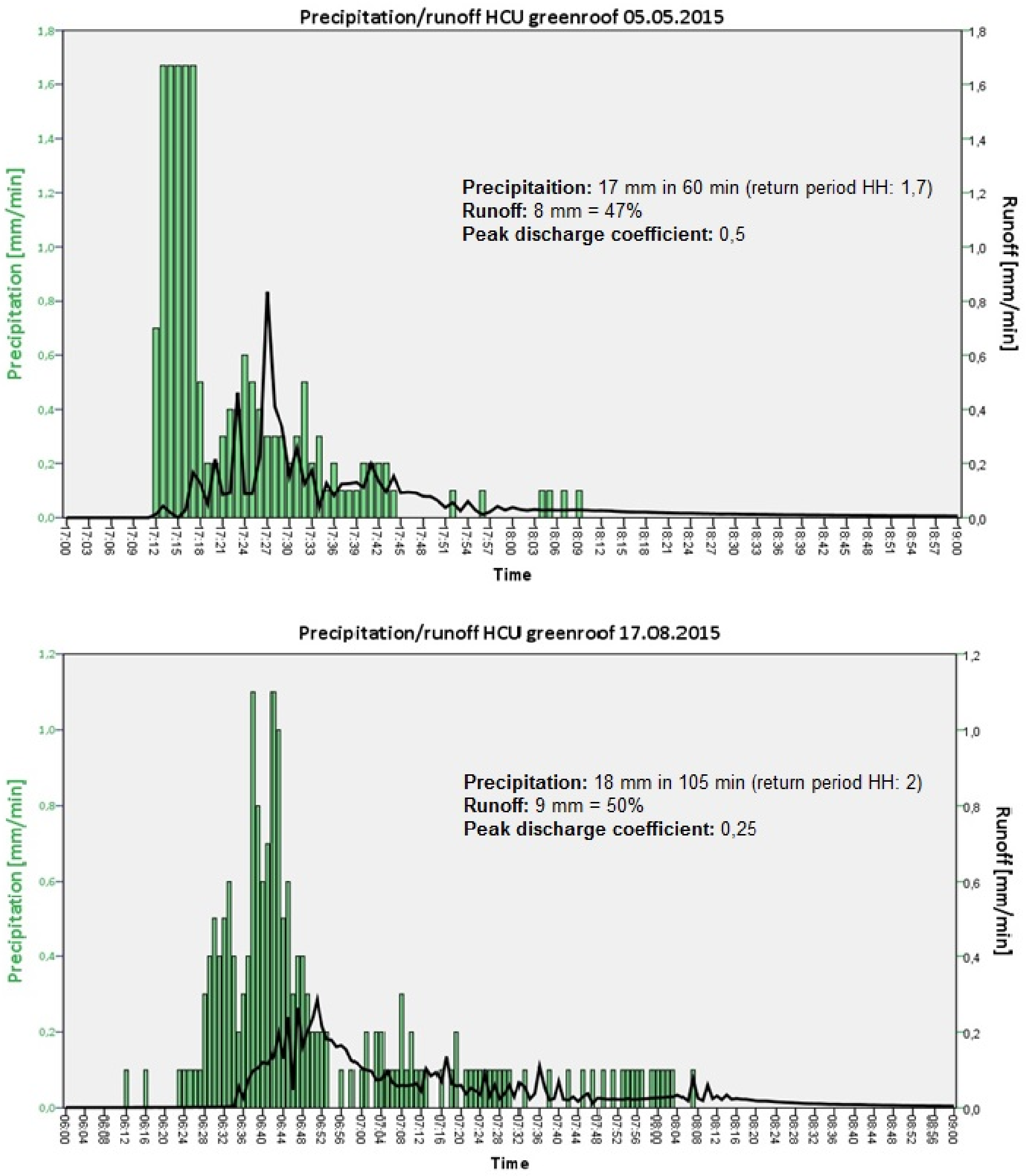

Fig. 4 Recorded heavy precipitation events on the HCU green roof (05.05.2015 and 17.08.2015)

4. Discussion

The results of the systematic review confirmed results of previous comparable studies of water management effects of green roofs ([16], [23], 24[]). Water retention over a year and in different seasons or months were reported as having the same order of magnitude (9-85% per year by [3]). Compared to the yearly retention values according to the FLL-guideline for green roofs ([20], see Fig. 5), the reviewed studies revealed greater retention performance of about 5-10% within each substrate thickness category, except the >100-150 mm category. This indicates a slight underestimation of the retention capacity of green roofs according to the guideline. The dependency of runoff retention on thickness of soil substrate, soil moisture content, precipitation intensity and duration, roof slope, season and latitude and their underlying causes are mostly known. In this meta-analysis, no significant correlations could be proved with vegetation cover, plant species composition, growing media type and roof age, which could be due to characteristics of the statistical method. For these attributes there are tendencies, but these could not be proved statistically significant due to the low number of published investigations on these attributes. For the whole picture, it is important to have these impacts of green roof characteristics in mind when targeting rainwater management. Nevertheless, even with knowledge of these characteristics it cannot be

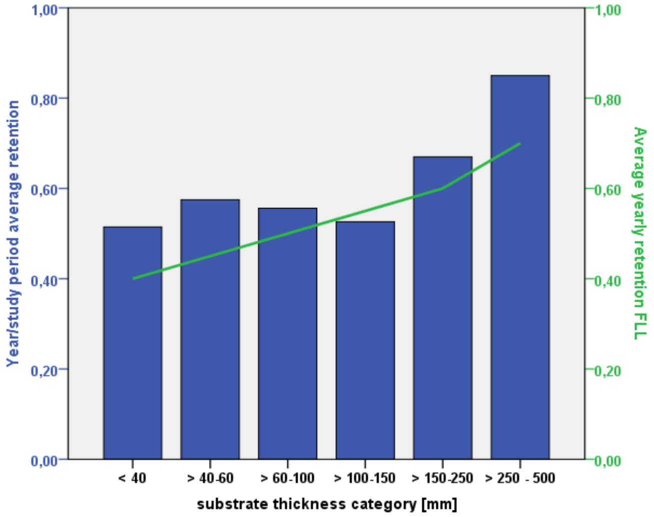

Fig. 5 Comparison of retention values of green roofs' substrate categories between FLL guideline and data from review

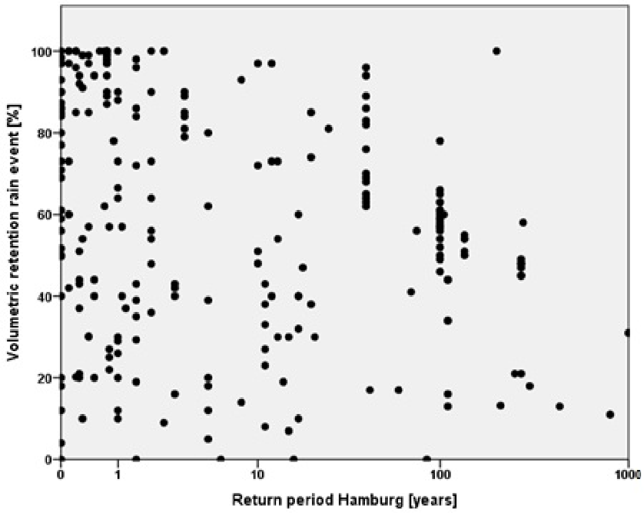

Fig. 6 Volumetric green roofs' retention of single rain events from reviewed studies (y-axis) and their comparison to Hamburg rain events expressed as return period (probability of occurrence) for Hamburg (x-axis, logarithmic)

guaranteed that desired effects will occur. For future rainwater management in cities and sewerage system design, the retention effects in case of heavy precipitation are of particular importance. It is still not cleared which amount of water can be retained and there are general doubts that green roofs, especially extensive ones, can contribute to decreasing urban flood risk in densely built urban quarters. At the moment, at least for Hamburg, green roofs are not considered to be an element of decentralized flood management practices. The review results, which include studies of green roofs all over the world, showed that it cannot be generalised whether green roofs have a significant retention effect or not. Figure 6 shows the outcome of an attempt to compare rain events from these studies with rain events from Hamburg. This was done by converting the rainfall amount [mm] and duration [min] of a single precipitation event into a return period for Hamburg. By applying specific extreme value statistics for heavy precipitation, every event was assigned a probability of occurrence (return period). For example a precipitation of 27 mm in 15 min had a return period of 100 years which means that the probability of occurrence is once in 100 years. It can be stated that there is a wide variety of volumetric retentions for most of the return periods. Even though the (linear) trend is slightly negative, which means that for greater return periods less retention would be expected, there are several events with return periods of, for example, 100 years where retention is over 50%. But nevertheless, there are also relatively small rain events (< 1 yearly) where there are retention values of less than 20%. This again indicates that the retention of green roofs is dependent on several technical and climatic values and that further research is needed in order to to generalize the effects influencing retention and to provide recommendations for stormwater management practices. The aim of the measurement system of the HCU green roof is to quantify these effects for the local climatic conditions of Hamburg. With ongoing measurement, a wide range of extreme precipitation events in the future will be recorded (return period of heaviest event up to now: 2 years, Fig. 4), which will lead to a better understanding of the underlying effects.

5. Conclusion

It has been demonstrated that green roofs can retain significant amounts of rainwater throughout the year (> 50%) and in this way have positive effects on the urban water cycle. But it is still unclear what amount of rainwater can be retained in case of extreme precipitaion events and therefore which contribution they can provide for urban stormwater management. By analysing precipitation events and related green roof retention it could be shown that there is a wide variety of characteristics (technical and climatological) that influence retention on a roof. Accordingly, no general statements towards retention capacity with increasing precipitation intensities and durations can be given. Therefore, the green roof measurement campaign on the HCU green roof is intented to collect data of a wide variety of (extreme) rain events and retention to draw conclusions for urban stormwater management. It would for example be interesting which type of green roof is suitable for comprehensive installation on roofs due to its cost-effectiveness and can retain large portions of heavy precipitation events to relieve the existing sewage network.

6. Acknowledgements

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EVALUATION OF RISKS ASSOCIATED WITH BONDS AND GUARANTEES IN CONSTRUCTION PROJECTS

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Summary

Construction bond was introduced to enhance performance of construction projects by protecting or indemnifying its recipients against projects' risks and problems, but the challenge over the years lies in the practical enforcement of bonding conditions and its overall benefits to the construction industry. This research therefore examined risks and problems inherent in projects with and without bonds, with a view to ascertaining their effects on construction projects sustainability. Primary data were collected through administration of questionnaires on identified construction bond stakeholders namely: clients of public projects: quantity surveying and architectural firms; and contracting firms. Questionnaires were administered on 337 respondents out of which 242 were returned while 236 were certified fit for analysis. Mean item score was used for ranking the identified factors while Kruskal-Wallis and Mann-Whitney tests were employed to examine relationship and differences in sample means of different groups of respondents respectively. Despite the high importance attached to usage of construction bonds, the study revealed that projects executed without these bonds and guarantee are more susceptible to problems and risk which can emanate during or after construction of projects. It also revealed that sustainable construction can be achieved through the use of bonds and guarantees. The study therefore recommended the need to adopt the use of construction bonds for all forms of projects either public or private as against the current practice where it is only mandated for public projects.

Keywords: construction stakeholders, construction bond, guarantee, risk

1. Introduction

Construction industry is plagued by diverse problems among which are project abandonment, building collapse, contractor insolvency, projects not delivered to time, cost and quality, etc. These are construction risks resulting in disputes/conflicts among stakeholders which may eventually lead to claims and award of damages. [1] asserted that construction industry is beset by risk and the industry has suffered poor performance as a result. This poor performance is related to projects not delivered to time, cost and quality. However, [2] concluded that the ultimate goal of any construction project is to be delivered in the shortest possible time, at the lowest possible cost and highest quality.

One of the ways of managing issues and conflicts arising from construction works is the use of bonds. According to [3], a construction surety bond is a financial instrument used generally when the first party (owner) has an agreement with a second party (Construction Company). This financial instrument serves as a guarantee to the first party from a third party (Surety Company) that a construction job (obligation) will be completed according to the terms and conditions within a written contract. A surety bond assures project owners, public or private, that the contractor has met the required standard evaluation of an independent third party (surety). This evaluation gives the project owner comfort and security knowing that the contractor runs a well-managed, responsible, and financially sound firm and has the experience necessary for the specific project. In a study on the purposes and implication of performance bond, [4] concluded that in the construction context, back-up or guarantor or surety or the third party is likely to come from one of these two sources: Parent Company Guarantee that has to do with the contractual performance of one company within a corporate group is underwritten by other members of the group; or Bonds, which is normally provided (at a price) by a financial institution such as a bank or an insurance company. [3] concluded that construction surety industry is undergoing serious problems and most of them are suffering financial looses. This study therefore examined proneness of construction projects executed with and without bonds and guarantee to constructions risks and problems.

2. Literature Review

2.1 Risks associated with Construction Bonds

A distinct characteristic of construction projects is risk [5] and one of the major ways of managing it is through the use of bonds. [6] observed that surety bonds and bank guarantee (or letter of credit in the US) are the two major instruments to protect the owners of a construction project against the risk of non-performance of the contractor. [7] opined that bonds is to indemnify the oblige against the default of the principal. Primarily, the contractor (principal) is shoulder to bear most construction risks and this is mostly transferred to the surety for an amount (e.g. bank interest charge, etc.) for a particular period of time depending on the contractual obligation and requirements.

A construction surety bond is a financial instrument used generally when the first party (owner) has an agreement with a second party (Construction Company). This financial instrument serves as a guarantee to the first party from a third party (surety company) that a construction job (obligation) will be completed according to the terms and conditions within a written contract. Construction bond is a risk sharing or transfer method and [8] argued that though the conventional wisdom seems to regard bond investment as being safe, the level of risk varies with the bond structure and terms of use. [9] concluded that the risky and hazardous nature of construction business makes the underwriting decisions crucial for sureties. One of the distinct characteristics of construction projects is that they are full of various risks and [5] opined that contract guarantee has proved to be an effective measure to defend against default risk.

[8] identified nine (9) types of risks associated with construction bond from literature. These include: credit risk, interest rate risk, liquidity risk, prepayment risk, reinvestment risk, currency risk, inflation risk, sovereign risk and volatility risk.

Credit risk refers to financial soundness of issuer. More explicitly, related to ability of issuer to make interest payments and return principal on schedule. Typical credit risk involves credit spread risk, downgrade risk, and default risk. Interest rate risk refers to sensitivity of bond prices to changing market conditions. Bond values move in opposite direction from prevailing interest rates. Liquidity risk is the risk for not effecting immediate redemption of bond at market value. If investors want to redeem bond at once, selling price will most likely be below market value. Prepayment risk relates to bonds redeeming by issuer before maturity; usually investors will receive less cash flow than expected. Reinvestment risk is the risk that payment of interest and principal at specific time may be reinvested at lower interest rate than original bond yield.

Currency risk is the risk of receiving less domestic currency when investing in bond issue that makes payments in currency other than domestic. Inflation risk is the value of bond's cash flows (both interest and principal) declines because of inflation. Sovereign risk results from actions undertaken by a foreign government; usually associated with credit risk. Bond credit will deteriorate after governmental actions. Consequently, poor credit rating will eventually drag down bond price. Volatility risk applies to bonds embedded with callable and putable options. Price reduction will be caused by change of expected yield volatility. Increase in expected yield volatility will raise value of callable bond but reduce value of putable bond, and vice versa

2.2 Sustainable construction

[10] defined sustainable construction as 'the sustainable production, use, maintenance, demolition, and reuse of buildings and constructions or their components'. In the opinion of [11], sustainable buildings and built environments are seen as 'the contributions by buildings and the built environment to achieving—components of—sustainable development'. [12] defined sustainable construction as 'a holistic process aiming to restore and maintain harmony between the natural and the built environments, and create settlements that affirm human dignity and encourage economic equity'. According to the last definition, sustainability goes beyond mitigating environment of construction activities. It raises the idea of restoring the environment, as well as highlighting the social and economic aspects of sustainability, explicitly defining what the goals for these aspects are. These are risks inherent in construction projects and one of the strategies for managing such risks is the use of bonds and guarantees.

3. Methodology

The population of this study are construction stakeholders in the Nigerian construction industry that are directly involved with the management of risks emanating from administration of bonds. These includes: Contractors (and sub-contractors), Clients of public projects as well as Consultants (Architects and Quantity surveyors) in Lagos and Ondo states, Nigeria. Guarantors, that is, banks and insurance companies were not involved in this aspect of this research because they are not directly involved in managing bond risks.

Various forms of validity and reliability tests were carried out. Content validity was achieved by ensuring that the survey carried out is based on factors identified from literatures which were modified to suit the study area. Face validity was achieved using pilot study. Pilot survey was carried out at the initial stage of the research in order to pre-test the instrument for data collection. In carrying out the pilot study, it was ensured that each of the group of respondents were contacted as appropriate using convenience sampling method. In order to ensure uniformity, four questionnaires each were administered on each group of respondents making a total of twelve (12). It was also expected that this diversity will provide for wide range of views. For contractors, it was ensured that quantity surveyors, architects, builders and engineers are the four respondents for the questionnaire administration in the selected construction firms. The same was also ensured for the clients in the selected government establishments. In the case of consultants, two (2) respondents each from quantity surveying and architectural firms were selected.

Nine (9) PhD holders and PhD students from within and outside the country were also involved in the pilot study for necessary corrections and suggestions on way to improve the study. Their comments, observations, suggestions and corrections were noted and incorporated into the final draft of the instruments for final survey.

Table 1 : Reliability test

Description	Asymptotic significance
Internal Reliability	
Occurrence of risks on project with bond	0.870
Occurrence of risk on projects without bond	0.898
Test-retest reliability	
Occurrence of risks on project with bond	0.530
Occurrence of risk on projects without bond	0.737
Parallel reliability	
Occurrence of risks on project with bond	0.000*
Occurrence of risks on projects without bond	0.018**

*** Significant at $p < 0.01$, ** Significant at $p < 0.05$.**

Interrater reliability was achieved by ensuring that questions in the research instruments for different categories of respondents are customized and adjusted based on the respondents' peculiarities but using the same set of factors and variables. For internal reliability, Cronbach's alpha (α) test was employed and the result in table 1 depict that the instrument used for the study is reliable since the values are close to 1.00. Test-retest reliability was achieved by examining the significance of the differences in the responses of respondents from Ondo and Lagos states using Mann-Whitney U-test (MW). The result in table 1 indicate that there is no significant difference in the opinion of respondents from the two states.

Parallel reliability was achieved in this study by comparing and correlating the response of different group of respondents using Kruskal Wallis K-test since the respondents are more than two groups. The results indicate that there is significant difference in the measured factors.

Table 2: Population and sampling frame of respondents

Respondents	Population	Sampling frame	Actual
Clients of public projects	53	53	46
Quantity Surveying firms	58	56	39
Architectural firms	84	79	33
Contractors	202	149	118
Total	**397**	**337**	**236**

Out of 379 identified population, only 337 could be reached after conducting an initial survey as indicated in table 2. Questionnaires were administered on these stakeholders using census method but due to time constraints and lack of commitment from some of the respondents, 242 of these were returned out of which only 236 were certified fit for further analysis (the remaining 6 questionnaires were not completely and correctly filled by the respondents). The 236 figure represents about 59% and 70% of the population and sampling frame respectively. This response rate is considered sufficient base on the assertion of [13] that the result of a survey could be considered as biased and of little significant if the return rate was lower than 20-30%.

4. Results

This section examines the level of occurrence of identified risks and problems in projects with and without bond. All the stakeholders were involved in responding to this aspect of the study and Kruskal-Wallis K-test in table 1 revealed an asymptotic significance value of 0.000 and 0.018 for bonded and non-bonded projects respectively. At 5% level of significance, the result signify that there is significant difference in the opinions of stakeholders as touching this aspect of the study.

4.1 Characteristics of Questionnaire Respondents

107 of 236 respondents are from Ondo state while the remaining 129 are from Lagos state of Nigeria. Of these figure, 118 are contracting firms representing about 50%, 72 are consultants, that is, architectural and quantity surveying firms while 46 are clients' organisation as indicated in table 2.

4.2 Occurrence of Risks and Problems on Bonded Construction Project

For bonded projects, table 3 denote the level of occurrence of risk factors and problems associated with such projects. Using ANOVA test, it could be observed that p-value for all the factors is 0.000 which indicate significant variance at both 10% and 5% level of significance. It can thus be concluded that there is significant difference in the opinion of respondents in responding to each of the factors in this aspect of the survey.

From contractors' perception, the first three factors in bonded projects are inflation, reinvestment and prepayment risk all coming under risk factors. It could be observed that only two of the first ten factors are from the identified problems. This showed that contractors believe that identified risks do occur more in bonded projects than the identified problems. Contrary to this, problems relating to increase in cost and time of construction projects are the most occurring in bonded projects from guarantors' perspective. In clients and consultants view, prepayment, interest rate and credit risk do occur more in bonded projects than other listed risk and problems. On the lower end, the least occurring factors from all the stakeholders' perception are the identified problems and they are related to reduced quality of construction project and building collapse.

From the general point of view, the most occurring risks in bonded projects are inflation, prepayment, interest rate and credit risk in descending order. For identified problems, the major ones are increase in cost and time of construction project and patronage of non-competent political contractor. Of the first ten factors, seven are risk factors while only three are project problems. In fact, the remaining two risk factors are occupying 11th and 12th position signifying that identified construction bonding risks are more inherent in bonded projects than the listed problems.

4.3 Occurrence of Risks and Problems on Projects without Bond

In considering the occurrence of identified risks and problems in construction project that are not bonded, ANOVA test was applied to assess the variance in mean values of each factors. Table 4 expressed the views and opinion of the three categories of stakeholders that were contacted for this study. The analysis revealed that P-value of eight of nine risk factors and six of project problems are less than 0.05. This implies that there is significant difference in mean values of these fourteen factors by construction stakeholders.

Table 3: Occurrence of risk and problems on projects with bond

Risks and problems	Contractors		Consultants		Clients		Guarantors		Overall		F-ratio	Sig. (p-value)
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank		
Risks												
Credit risk (Financial soundness of issuer)	2.86	7	3.94	2	3.89	3	4.14	3	3.51	4	59.156	0.000*
Interest rate risk (Bond sensitivity to changing market)	3.05	4	3.79	3	4.04	2	4.08	4	3.56	3	35.080	0.000*
Liquidity risk (Difference in market value and selling price)	2.73	9	2.94	7	3.00	7	4.02	5	3.03	8	28.663	0.000*
Prepayment risk (Bond redeemed by issuer before maturity)	3.15	3	4.03	1	4.11	1	3.35	15	3.57	2	18.272	0.000*
Reinvestment risk (Change of value of amount of bond)	3.59	2	2.89	8	2.85	9	3.45	11	3.26	6	13.972	0.000*
Currency risk (Difference in currency exchange rate)	2.90	6	2.54	11	2.67	11	3.53	9	2.86	10	9.302	0.000*
Inflation risk (Economy instability)	3.96	1	3.25	6	3.35	5	3.63	8	3.62	1	7.711	0.000*
Sovereign risk (Action from foreign government)	2.51	11	2.67	10	2.80	10	3.28	16	2.71	11	7.575	0.000*
Volatility risk (Bonds with callable and putable option)	2.79	8	2.26	15	2.41	13	3.50	10	2.69	12	11.497	0.000*
Problems												
Project abandonment	2.17	16	2.29	14	2.33	14	3.90	7	2.49	14	45.507	0.000*
Absconment of contractor	2.08	17	2.17	16	2.30	15	3.19	18	2.31	17	17.235	0.000*
Patronage of non-competent political contractor	2.29	15	3.46	5	3.28	6	3.45	11	2.93	9	24.988	0.000*
Increase in cost of construction project	2.93	5	3.75	4	3.61	4	4.24	2	3.45	5	15.404	0.000*
Increase in duration (time) of the project	2.72	10	2.86	9	2.89	8	4.43	1	3.04	7	37.751	0.000*
Reduced quality of the project	2.07	18	1.86	18	1.91	19	3.93	6	2.27	18	75.839	0.000*
Building collapse	2.37	12	1.64	19	1.93	18	2.69	19	2.16	19	11.581	0.000*
Contract failure	2.31	14	1.97	17	2.20	16	3.45	11	2.37	15	36.915	0.000*
Dispute/Conflicts	2.37	12	2.47	12	2.61	12	3.36	14	2.59	13	10.350	0.000*
Poor working relationship between project team members	2.07	18	2.42	13	2.20	16	3.21	17	2.35	16	14.309	0.000*

*** Significant at $p < 0.01$, ** Significant at $p < 0.05$.**

Table 4: Occurrence of risks and problems on projects without bond

Risks and problems	Contractors		Consultants		Clients		Overall		F-ratio	Sig. (p-value)
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank		
Risks										
Credit risk (Financial soundness of issuer)	2.10	15	2.13	19	2.65	19	2.22	18	5.555	0.004*
Interest rate risk (Bond sensitivity to changing market)	1.73	19	2.32	18	2.74	18	2.13	19	18.000	0.000*
Liquidity risk (Difference in market value and selling price)	2.74	11	3.64	7	3.76	7	3.24	8	20.862	0.000*
Prepayment risk (Bond redeemed by issuer before maturity)	2.08	16	2.68	16	2.91	17	2.44	15	15.237	0.000*
Reinvestment risk (Change of value of amount of bond)	2.04	17	2.60	17	2.93	16	2.40	16	17.384	0.000*
Currency risk (Difference in currency exchange rate)	2.36	13	3.31	11	3.43	11	2.89	14	24.089	0.000*
Inflation risk (Economy instability)	3.00	9	2.71	15	2.96	15	2.90	13	1.309	0.272
Sovereign risk (Action from foreign government)	2.21	14	4.06	2	3.87	5	3.15	9	69.438	0.000*
Volatility risk (Bonds with callable and putable option)	1.74	18	2.83	14	3.07	14	2.37	17	53.349	0.000*
Problems										
Project abandonment	3.23	6	3.90	4	3.93	3	3.57	6	10.183	0.000*
Absconment of contractor	3.44	4	3.71	5	3.87	5	3.60	5	3.887	0.022**
Patronage of non-competent political contractor	3.95	1	3.38	9	3.57	8	3.70	3	4.998	0.007*
Increase in cost of construction project	3.16	7	2.94	13	3.24	12	3.11	10	1.849	0.160
Increase in duration (time) of the project	3.81	2	3.47	8	3.57	8	3.66	4	2.813	0.062
Reduced quality of the project	3.37	5	4.14	1	4.20	1	3.77	1	15.526	0.000*
Building collapse	2.72	12	3.32	10	3.48	10	3.05	11	11.295	0.000*
Contract failure	3.57	3	3.99	3	3.91	4	3.77	1	3.028	0.050
Dispute/Conflicts	3.09	8	3.68	6	4.00	2	3.45	7	7.188	0.001*
Poor working relationship between project team members	2.89	10	3.10	12	3.17	13	3.01	12	2.498	0.084

*** Significant at $p < 0.01$, ** Significant at $p < 0.05$.**

For the remaining five factors, that is, inflation risk and problems associated with increase in cost and time of project, contract failure and poor working relationship between project team members, it could be concluded that there is no significant difference in the opinion of respondents concerning them.

All the stakeholders were of the opinion that the most occurring factors in construction projects that are not bonded are the problems, and not the identified risks. This is evident in the fact that the first eight factors from all the stakeholders' view are located within the identified problems. The most occurring problems in construction projects that are not bonded from contractors point of view are patronage of non-competent political contractor and increase in duration of construction projects. Clients and consultants concur that reduction in quality of construction project arise most in projects that are not bonded. The least occurring factors are located within risk sub-factors. These are volatility risk from contractors' view and credit risk from clients and consultants point of view.

The most occurring construction problems associated with bonded projects on a general view are contract failure and reduced quality of construction project while the least has to do with poor working relationship between project team members. From the identified bonding risks, liquidity and sovereign risks have the tendency of occurring most in contrast to credit and interest rate. Furthermore, it could be observed that the most occurring risk factors, that is, liquidity and sovereign risk are on the average while the rest are far below average. This cannot be said of the problems as most of them have a high level of occurrence.

4.4 Occurrence of Risks and Problems on Construction Projects

Mean gap and Mann-Whitney U-test were employed in examining the relationship between occurrence of risks and problems in construction projects with and without construction bond. Mean value calculated in table 5 revealed that identified risk factors associated with bonded projects are higher than of projects without bond. In contrast, problems of bonded projects are found to be lesser than that of project without bond. This implies that identified risk factors are more inherent in bonded construction projects while construction problems occurs more in project that are not bonded.

For construction projects, all the identified risks are higher in bonded construction projects except for liquidity, currency and sovereign risk. It could be deduced that these three risk factors can arise in construction projects regardless of whether such is bonded or not. Furthermore, the study also revealed that all the identified problems have a higher level of occurrence in construction projects without bond except for increase in cost of construction which is peculiar to all forms of construction projects.

In order to further ascertain the difference in the occurrence of risks and problems associated with construction projects with and without bond, Mann-Whitney U test was adopted since there are two samples. The analysis indicate a Z value of -2.075 and an Asymp. Sig. (2-tailed) value of 0.004. This revealed that there is significant difference in the occurrence of risks and problems in projects with and without bond. This also implies that while the identified risk do occur more in bonded projects, the identified problems are more inherent in construction projects that are not bonded. It therefore mean than use of construction bonds is an effective tool for sustainability in the building sector since it helps in minimising risks and problems which are key to achieving sustainable construction projects.

Table 5: Risks and problems on projects with/without bond

Risks and problems	With bond		Without bond		Mean
	Mean	**Rank**	**Mean**	**Rank**	**Gap**
Risk *Average*	*3.20*		*2.64*		*0.56*
Credit risk (Financial soundness of issuer)	3.51	4	2.22	18	1.29
Interest rate risk (Bond sensitivity to changing market)	3.56	3	2.13	19	1.43
Liquidity risk (Difference in market value and selling price)	3.03	8	3.24	8	-0.22
Prepayment risk (Bond redeemed by issuer before maturity)	3.57	2	2.44	15	1.12
Reinvestment risk (Change of value of amount of bond)	3.26	6	2.40	16	0.86
Currency risk (Difference in currency exchange rate)	2.86	10	2.89	14	-0.03
Inflation risk (Economy instability)	3.62	1	2.90	13	0.73
Sovereign risk (Action from foreign government)	2.71	11	3.15	9	-0.44
Volatility risk (Bonds with callable and putable option)	2.69	12	2.37	17	0.32
Problems *Average*	*2.60*		*3.47*		*-0.87*
Project abandonment	2.49	14	3.57	6	-1.09
Absconment of contractor	2.31	17	3.60	5	-1.30
Patronage of non-competent political contractor	2.93	9	3.70	3	-0.77
Increase in cost of construction project	3.45	5	3.11	10	0.34
Increase in duration (time) of the project	3.04	7	3.66	4	-0.62
Reduced quality of the project	2.27	18	3.77	1	-1.50
Building collapse	2.16	19	3.05	11	-0.89
Contract failure	2.37	15	3.77	1	-1.39
Dispute/Conflicts	2.59	13	3.45	7	-0.86
Poor working relationship between project team members	2.35	16	3.01	12	-0.66

5. Discussion

From the finding of this study, it could be observed that all identified risks are inherent in projects executed with construction bond except liquidity and volatility risks. This could be attributed to the fact that all the identified risk factors are peculiar to construction projects executed with the use of bond and guarantee. Credit risk is the most common to projects with construction bond and this is supported by the [8] where credit risk that is concerns with the financial soundness of the issuer is listed as the first risk factors associated with construction bond.

The study further revealed that all identified construction problems are more inherent in projects executed without bond except for increase in cost of construction project. In support of the findings, [14] observed that jobs that are bonded are much more likely to be completed without problems while [15] identified the following benefits of guarantee to contractors: enhance credibility; enhance contract facilitation; and enhance better cash flow. These are the basic requirements for sustainable construction as noted by [11] indicating that usage of bonds and guarantee can aid social, financial and enviromental friendly projects. On the only problem associated with bonded project, that is, increase in cost of construction, [16] identified increase in initial bid as the major disadvantage of bond provision.

6. Conclusion

Generally, bond risks are more inherent in bonded projects since they are identified for such type of projects. A major notable problem with bonded construction projects is that it increase cost of construction projects which is related to economic aspect of sustainability. However, this cost which is diretcly related to administration of construction bonds can be accomodated by client in as much as such projects are delivered to cost, time, quality, energy efficiency, friendly environemnt and satisfaction of the client, owner or sponsor. Other construction problems such as contract failure, project abandonment, dispute and conflicts, poor quality, etc. are more inherent in projects that are not under any of the identified construction bonds. This implies that sustainable and economic construction devoid of common risks and problems can be achieved through the use of bonds and guarantees. Such projects will not only be socially viable but will also be environemtally friendly. It is therefore necessary to adopt the use of bonds and guarantees in all forms of projects either public or private against current practice where it is only mandated for public projects. This will be of great help in minimizing problems associated with infrastructural projects and thereby, enhance sustainable construction projects.

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Evaluation of Sustainable Infrastructure - Using the Southern Quay of the Island of Heligoland as a Case Study

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Summary

The construction sector and infrastructure projects in particular have a significant impact on the environment. In an effort to minimise these adverse environmental effects, the building industry has developed numerous sustainability rating systems. In regard to infrastructure most of the rating systems focus, however, on bridges and roads, leaving out other sectors with enormous environmental optimisation potentials. To bridge this gap, a sustainability rating tool focusing on the ecological dimension of sustainability has been developed for port infrastructure projects. We ran a life cycle assessment on a major deep-sea quay construction project on the Island of Heligoland in the North Sea. Our goal was to find the most climatically sound option between a king post wall and four different types of sheet pile structures. The results show that the king post wall is the best planning option. More important, however, is that our approach is successful in selecting climatically sound planning options for port infrastructure projects, beginning to make sustainability rating systems available for infrastructure projects.

Keywords: Sustainable Infrastructure Projects, Life Cycle Assessment, Port Infrastructure, Waterway Engineering, Island of Heligoland

1. Introduction

The newest report from the International Panel on Climate Change (IPCC) shows that greenhouse gas (GHG) emissions have continually increased since the 1970s. The building sector contributes significantly to the overall GHG emissions [1]. In 2010 for instance, 6.4 % of the global GHG emissions were released by the building sector. This clearly shows that the construction sector and infrastructure projects in particular have a significant impact on the climate. In an effort to minimise these adverse environmental effects, the building industry has developed numerous sustainability rating systems such as the German Sustainable Building Certificate (DGNB). These rating systems allow assessing the sustainability of buildings by providing a measurement of environmental performance. For infrastructure, however, most existing rating systems rather encourage sharing sustainable best practices, as shown by a study on international rating systems by Clevenger et al. [2]. Most of these rating systems focus on bridges and roads, leaving out other sectors with enormous optimisations potentials. To bridge this gap, we at WTM Engineers have made an important step towards a sustainability rating tool for port infrastructure projects, building on our expertise, e.g. in waterway engineering and making use of life cycle assessments (LCAs).

Our approach focuses on the ecological dimension of sustainability, following a study by Graubner and Mielecke that started to make rating available for bridges [3]. We ran an LCA on a major deep-sea quay construction project on the Island of Heligoland in the North Sea. The Local Government Authority decided to build a new offshore quay to move the island’s supply away from an existing and overcrowded passenger-terminal. Supporting this project, WTM Engineers have been responsible for major civil engineering works in the reconstruction of the new southern quay with its adjacent onshore area. Our goal was to find the most climatically sound option between a king post wall and four different types of state-of-the-art sheet pile structures. The results show that the king post wall is the best planning option with e.g. the lowest climate footprint over 100 years. More important, however, is that our approach is successful in selecting climatically sound planning options for port infrastructure projects, beginning to make sustainability rating systems available for projects beyond bridges and roads.

2. Methodology

2.1 Life Cycle Assessment in line with DIN EN ISO 14040

Given Heligoland’s remote location in the deep sea, the local government opted for a long-lasting and sustainable solution that would minimise the need for costly maintenance and replacement throughout the lifetime of the quay. We subsequently ran an LCA in line with DIN EN ISO 14040 where we considered the project’s entire life span - from the acquisition of raw materials to their use and final disposal - for a period of 100 years. We ran LCAs for each of the five building options, the king post wall and four different types of state-of-the-art sheet pile structures to verify if the pre-selected and constructed king post wall really is the climatically sound solution.

An LCA is typically run in four interacting phases [4]. The goal of the LCA and the scope are defined in the first phase. This includes a clear definition of the system boundary, i.e. which processes in constructing and maintaining a specific infrastructure project are to be analysed and which are not, and the level of detail. In order to compare two systems, it is equally important to define a measure of reference that is consistent between the two systems. This reference unit is termed as functional unit in the DIN EN ISO 14040 and can comprise e.g. a quantity or duration. The next phase is a life cycle inventory analysis (LCI) where all flows crossing the defined system boundary, e.g. raw materials, fossil fuels, are identified and recorded in terms of bulk material quantities. This is an essential step that brings detailed information on all energy and material flows needed to construct, maintain, renew and deconstruct the pre-defined system and that are the key drivers of sustainable performance of an analysed system. The climatic impact of each of these flows in the LCI is then assessed using so-called impact categories in the life cycle impact assessment (LCIA) phase. These impact categories represent the climatic issues of concern, e.g. the climate footprint and the global warming potential. Once the impact categories of interest are selected, each bulk material in the flows in the LCI is multiplied with a so-called characterisation factor that quantifies the climatic impact for each bulk material across its lifetime in measurable units, e.g. in carbon dioxide equivalents. The resulting indicators allow comparing the climatic impact across different types of bulk material quantities. The sum across all bulk material quantities in the pre-defined system, under consideration of differences in lifetime etc. across different materials, gives the overall climatic impact of the entire system that was defined in the first phase.

These three phases culminate in the final phase, a life cycle interpretation with a summary and discussion as starting point for conclusions and decision-making in compliance with the pre-defined overall objective of the LCA.

2.2 Running a Life Cycle Assessment on a Port Infrastructure Project

Phase 1: Setting the Goal and Defining the Scope

Applying these four phases on our case study on Heligoland, we firstly determined the system boundaries of our project in a way that includes all measures and construction components with a direct link to a quay structure. Our LCA system includes all works to safeguard the existing construction, to stabilise the onshore areas serving as transhipment areas and, in particular, to stabilise the quay by the use of a king pile wall, and to secure the foundation and the structural equipment of the quay. We did not take into account other project specific measures, such as the demolition of a former wind power plant.

Our goal was to select the climatically sound option between four different types of state-of-the-art sheet pile structures and a king post wall called for considering differences in these options' service life times, and for finding a functional unit to compare LCA-results across the five quay options. For service life times, Graubner et al. show that civil engineering structures have a great social significance and often stay in service for more than 100 years [3]. Our experience in waterway engineering go in the same direction with king post walls lasting for roughly 100 years, while sheet pile structures typically need a replacement every 15 to 60 years. That is to say that each of the four sheet pile structures would need three replacements across the envisaged quay service lifetime of 100 years while the king post wall would not need to be replaced.

Finding a functional unit for meaningful comparisons across the five quay options was particularly difficult. Constructing each of these five options would require a different amount of bulk materials due to different dimensions. These different dimensions naturally translate into significant variations in climatic impacts simply caused by quay option-specific construction requirements. While this difference in climatic impacts is an interesting finding in itself, we decided to go much deeper and to find a way to control for this inherent bias by comparing the yearly climatic impact of each of the five different quay options based on a 1 m long quay structure with a 1 m deep main load-bearing component. We identified these parameters as key construction requirement-unspecific drivers for the quay structure's climatic impact based on numerous expert interviews with our in-house waterway engineers and a review of recommendations on minimum construction standards for waterfront structures from the German Committee for Waterfront Structures [5]. The minor caveat of this approach is that we could not validate the accuracy of this functional unit given the lack of relevant studies on evaluating the sustainability of waterfront structures.

Phase 2: Inventory Analysis

We then inventorised all flows crossing our pre-defined LCA system boundary during the lifetime of the five different quay options. These flows include bulk material quantities etc. needed for construction. Data on necessary bulk material quantities etc. was taken e.g. from the tender documents for the king post wall and through estimations from our project's preliminary design for the other four quay options. We complemented this inventory analysis with supplementary information that were missing in the tender documents, e.g. the specific weight of subordinated structural elements or the choice of corrosion inhibiting coating taken from suppliers' product declarations. The result was a detailed inventory of all bulk material quantities, services, etc. needed for the construction of each of the five quay options.

Our experience in waterway engineering is that for some processes in constructing and deconstructing a quay, it is difficult to make fully accurate predictions across its lifetime, e.g. for transportation services for material, machinery and men. Still wanting to account for these processes' effect, we followed an approach developed by Graubner et al. who use construction process specific interpolations factors that show by how much these processes increase the general adverse climatic effects of a construction project across its lifetime [6].

For a better comparison across the quay options, we took nine general processes in constructing a quay that are similar across the five different quay options, e.g. groundworks, dwelling etc., and then organised the collected data on necessary bulk material quantities etc. for each of the five options in these construction processes. This allows going much deeper in the comparison of climatic impacts across the five options.

Phase 3: Impact Assessment

The climatic performance of each of the nine general construction processes was then taken from data on material-specific environmental impacts taken from ökobau.dat [7], a German database for building materials, and company-specific environmental product declarations (EPDs) [8]. Both data sets provide product-specific characterisation factors for seven impact categories. Looking at these different impact categories allowed us to evaluate the climatic performance of each of the quay options relevant to different climatic issues of concern (see Table 1). We then calculated the climatic impact per process i and impact category k for each of the five quay options as the product of the number of replacements for each structural component over 100 years, n; the accumulated inventarised bulk material quantities per process i, m_i; construction process specific interpolation factors g_i; and the sum of all characterisation factors per life cycle LP and impact category k across all processes and for each bulk material, see also equation (1).

$$W_{i,k} = n \times m_i \times g_i \times \sum C_{LP,k} \tag{1}$$

A challenge was the traditional planning process for the quay in Heligoland where all five planning options were studied in a preliminary design phase, while only one planning option, the king post wall, was selected for the tender phase. The difficulty is that the bulk material quantities from the tender documents cover every little detail, while preliminary planning designs, in contrast, typically include informed estimates only. The consequence is that drafts from the preliminary design are generally not as elaborated as drafts from the tender documents, eventually leading to less exact results on climatic impacts. We first ran an LCIA for the king post wall based on the tender documents to get a distinct result on the climatic impact of the king post wall. However, we found only minor deviations when comparing LCA results for the king post wall using information from the tender phase and from the preliminary design, encouraging us to compare our LCA analysis across the five quay options based on their preliminary design.

Phase 4: Interpretation

The interpretation of our results was an important step in our case study. A dedicated team of planners analysed the LCA results and engaged in numerous discussions. Their input was vital to both, the interpretation of actual findings as shown in Section 3, and to the life cycle interpretation with a summary and a discussion as included in Section 4.

3. Results

3.1 LCA Results for the King Post Wall based on the Tender Documents

The climatic impact for each of the nine processes in constructing the king post wall and per each of the seven impact categories is shown in Table 1, with bulk material quantitates based on the tender documents.

Table 1: LCA for King Post Wall based on the Tender Documents

No.	Process	PERE	PENRE	GWP	ODP	AP	EP	POCP
		MJ	MJ	$kgCO_2e$	$kgCFC_{11}e$	$kgSO_2e$	$kgPO_4e$	kgC_2H_4e
1	Earthworks	0.17	2.94	0.23	1.4E-10	9.1E-04	2.0E-04	-7.4E-05
2	Foundation	2.10	42.88	4.52	3.7E-09	8.9E-03	1.1E-03	1.7E-03
3	Concrete Works	1.21	18.68	3.07	6.8E-09	5.0E-03	7.7E-04	7.5E-04
4	Steel Works	0.15	3.08	0.22	2.3E-10	4.3E-04	4.1E-05	8.4E-05
5	Corrosion Inhibiting Coating	0.19	2.92	0.22	5.1E-10	4.6E-04	4.1E-05	3.8E-04
6	Securing of the Foundation	0.29	10.59	2.97	6.4E-08	3.6E-03	5.2E-04	4.3E-04
7	Power Line Construction Works	0.08	1.39	0.08	6.2E-10	1.5E-04	2.4E-05	5.4E-05
8	Onshore Area Stabilisation	0.22	3.21	0.40	3.4E-10	8.0E-04	1.5E-04	-1.8E-05
9	Technical Equipment/ Use	5.51	40.16	2.97	1.2E-09	3.4E-02	3.5E-03	2.0E-03
Total Amount		9.91	125.85	14.67	7.8E-08	5.5E-02	6.4E-03	5.3E-03

PERE: Primary Energy Renewable; PENRE: Primary Energy Non-Renewable;
GWP: Global Warming Potential; ODP: Ozone Depletion Potential; AP: Acidification Potential;
EP: Eutrophication Potential; POCP: Photochemical Ozone Creation Potential

These results indicate that the foundation (process no. 2), the concrete works (no. 3), the securing of the foundation (no. 6) and the technical equipment/ use (no. 9) have the greatest impact on the environment. A general finding is that the larger the bulk material quantities required for a process, the higher is the climatic impact of a quay structure.

It is hardly surprising that foundation-related processes (no. 2, 3 and 6) make up for 57.3 % of the PENRE and 71.9 % of the GWP, given that foundation elements make the biggest part of waterfront structures. A more interesting finding is that the securing of the foundation is almost solely responsible for depleting the ozone layer (ODP: 82.1 %) and acidifying the air (AP: 61.8 %). Technical equipment and the use of the quay (no. 9), e.g. for moving goods and illuminating the onshore area, is equally responsible to the climatic impact and causes 31.9 % of the PENRE and 20.2 % of the GWP.

3.2 Comparison between Tender Documentation and Preliminary Design

When comparing these results with LCA results based on the preliminary design, we found only minor deviations. Fig. 1 shows that the results from the tender documents and from the preliminary design differ mainly for technical equipment and the use of the quay (process no. 9). The explanation for this deviation is that the main intention of the preliminary design phase is to analyse a project's background and to agree on project-specific goals. Detailed information on the use or technical equipment is usually not part of the preliminary design phase. The results become subsequently almost identical when process no. 9 is excluded from the comparison, as shown in Fig. 1. That is why we concluded that drafts from the preliminary design could generally be used for LCA studies on quay structures.

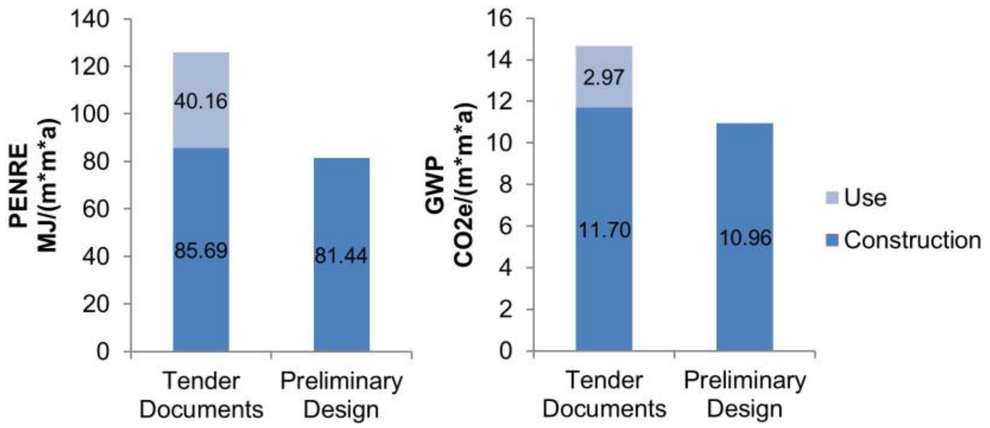

Fig. 1 Comparison of the King Post Wall Between Planning Phases over 100 Years

3.3 Comparison of all five Planning Options

We finally compared LCA results across all five quay options to find the climatically sound planning option. Given the previous findings, we used bulk material estimations from the preliminary design phase. Controlling for the differences in depth and length between the quay options, we used the functional unit of the yearly climatic impact of a 1 m long quay structure with a 1 m deep main load-bearing component for meaningful comparisons. We moreover focused on the two most important climatic impact categories within the construction sector, namely PENRE and the GWP.

Table 2: LCA Results of all Versions from the Preliminary Design

Quay Option	Construction	Functional Unit	Life Expectancy	PENRE MJ/ (m·m·a)	GWP $kgCO_2e$/ (m·m·a)
1	King Post Wall HEB 450, 11.85m, l = 195 m	4.43E-06	100	81.44	10.96
2	12.4 m Sheet Pile Wall, AZ38-700N, S355, l = 200 m	4.03E-06	25	318.51	38.97
3	12.4 m Sheet Pile Wall, AZ40-700N, S390, l = 200 m	4.03E-06	25	327.59	39.86
4	12.4 m Sheet Pile Wall, AZ40-700N, S355, l = 200 m	4.03E-06	25	324.55	39.59
5	12.4 m Sheet Pile Wall, AZ46, l = 200 m	4.03E-06	25	364.58	43.46

PENRE: Primary Energy Non-Renewable; GWP: Global Warming Potential

The results in Table 2 indicate that the king post wall has the lowest climatic impact. It has a demand of non-renewable primary energy of 81.44 MJ/(m·m·a). It becomes clear that the demand of the sheet pile walls is about four times higher, ranging from 318.51 MJ/(m·m·a) to 364.58 MJ/(m·m·a). This tendency is still the same when looking at the global warming potential. The king post wall comes to GWP emissions of 10.96 kgCO_2e/(m·m·a) - just about a quarter of those of the sheet pile walls, which range from 38.97 kgCO_2e/(m·m·a) to 43.46 kgCO_2e/(m·m·a). A possible explanation is the number of replacements across the service life of 100 years, with no replacement of the king post wall but three replacements of the sheet pile walls. Learning that the results of the king post wall are about four times lower than the results of the sheet pile walls, the results clearly show that replacements increase the climatic impact of constructions. Thanks to a longer lifetime, the king post wall comes to a lower climatic impact across 100 years despite higher emissions when constructed first.

We already showed that the bulk material quantities have a major influence on the climatic impact of a process in constructing a quay and thus of the quay itself. Our five quay options, however, use different amounts of building materials each. Controlling for the inherent differences in bulk materials and given the fact that quays are mainly made out of concrete and steel, we were then interested in how much steel, concrete and backfill contribute to the climatic impact - the use of PENRE and the GWP - of the king post wall, and the sheet pile wall with the lowest climatic impact (option no. 2 from Table 2).

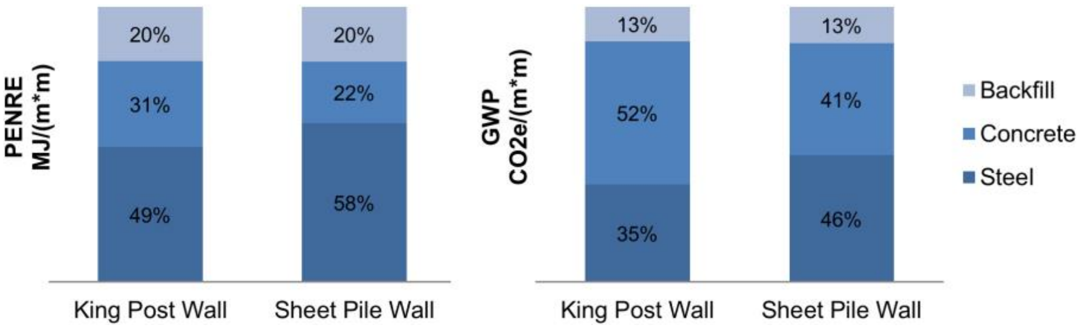

Fig. 2 Comparison between King Post Wall and the Sheet Pile Wall

Our findings in Fig. 2 show that concrete and steel have a bigger effect on the climatic impact than backfill and this finding is the same for both quay options and both impact categories. However, concrete elements have a stronger effect on the GWP (king post wall 31 % of total climatic impact; sheet pile wall 22 %) than on the use of PENRE (king post wall 52 %; sheet pile wall 41 %). Analogous, but the other way around, are the climatic impacts caused by steel elements. The emissions leading to global warming are generally lower (king post wall 35 %; sheet pile wall 46 %) whereas the emissions caused by the use of non-renewable primary energy are higher (king post wall 49 %; sheet pile wall 58 %). Backfill, in contrast, has a stronger effect on the use of PENRE (20 % across both quay options) than on GWP (13 %). In brief, these results indicate that concrete or, more exactly, its high proportion of cement, influence the GWP more than the use of PENRE. Steel, in contrast, affects the use of PENRE more than the GWP [9].

4. Discussion

Our objective was to select the climatically sound planning option for port infrastructure projects and specifically for the southern quay at the Island of Heligoland. Our key finding is that the king post wall is the best planning option over a service life of 100 years, with a climatic impact four times lower than for the sheet pile wall options. An important explanation for this finding is the difference in life expectancy and the need to replace sheet pile walls four times in 100 years - with enormous adverse climatic effects.

The reason for this difference in life expectancy between the king post wall (100 years) and sheet pile walls (25 years) in sea water is that steel is less lasting than concrete due to its relatively limited corrosion resistance to sea water. The life expectancy of a quay structure, however, is highly depending on the quay's load-bearing capacities. Once these load-bearing capacities are no longer given, the quay must be replaced. This risk is reduced for king post walls, with reinforced concrete elements well protecting the main load-bearing steel components against corossion caused by salt from sea water. The sheet pile wall is yet directly exposed to sea water resulting in a lower life expectancy than the king post wall.

A thicker sheet pile wall may increase the life expectency of quays based on sheet pile structures, according to the German Committee for Waterfront Structures [5]. Corrosion inhibiting coating could increase the life expectancy by 15 years, regular maintenance by further 10 years. We were keen to check if these improvements would change our findings on adverse climatic effects and extended the expected service life by 10 years and again 25 years for the best sheet pile option from Fig. 2. We then compared the global warming potential for the king post wall and the regular sheet pile wall with a life expectancy of 25 years (three replacements), a thicker sheet pile wall with an expected service life of 35 years (two replacements) and a thicker sheet pile wall with corrosion inhibiting coating and improved maintenance a life expectancy of 60 years (one replacement). The results in Fig. 3, however, show that across a service life of 100 years, sheet pile walls will always have a bigger effect on the GWP as they need to be replaced no matter what additional protective measures are taken. That is to say that the king post wall is still the more sustainable planning option even if sheet pile structures would see substantial improvements.

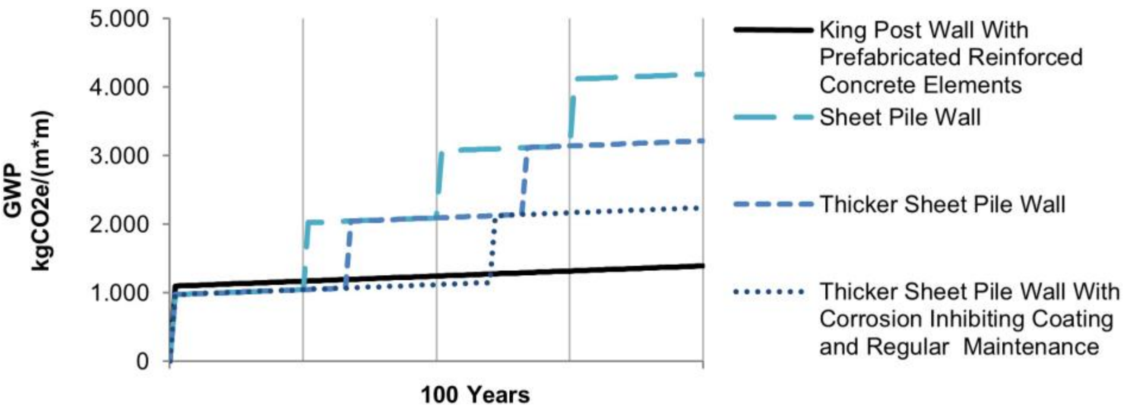

Fig. 3 Global Warming Potential over a Period of 100 Years for Different Planning Options

Our results show moreover that the higher the bulk material quantities required for building a quay, the higher is the climatic impact of a quay structure. This inituitive finding suggests that quay structures that need less bulk material quantities have less adverse envrionmental effects. Although to our knowledge, this study is the first to develop a sustainability rating system for port infrastructure projects, our finding is consistent with a study done by Graubner et al. on LCAs for bridges [6]. The key question resulting from this finding is if and how bulk material quantities could be reduced in future quay building projects. The answer to this question is quite complex and needs substantial further research, as the thickness and depth of a quay structure, that set the necessary bulk material quantities, depend highly on other citical parameters, e.g. the size of the ships mooring at the quay. An immediate solution would be to strengthen the use of building materials with lower climatic impacts, yet these materials tend to be more expensive than traditional building materials.

Another important implication of our study is that concrete has a bigger effect on the global warming potential than on the use of non-renewable primary energy, while steel influences PENRE more than the GWP. An explanation is that cement, the greatest proportion of concrete, releases large amounts of carbon dioxide during the burning process when produced. Steel, in contrast, consumes a lot of energy during the melting process.

Although our findings are promising, there are three important limitations. First, the life expactancy and the service life are just estimations and could be totally different in reality requiring more research in the future. Second, our analysis took place after the Government of Heligoland had already chosen the king post wall. While this proved to be the right choice, LCAs should usually be run in the planning process after the preliminary design phase so that they can inform the choice of a final design. Third, and most importantly, is that our LCA results depend on many external factors that are likely to change over time. For example, the way of constructing port structures or the building materials may change over a period of 100 years, possibly leading to different results. This limitation is driven by our finding that the use of a quay plays a major role for its climatic impact. In addition, our input data taken from ökobau.dat are only valid for a certain period and may change over time. It would hence be rewarding to repeat our analysis with an update on building materials, bulk material quantities and characterisation factors.

It is important to say that LCAs are a powerful tool to measure the estimated climatic impact at a certain point in time, i.e. in the planning process, but that LCA results are not valid for a long time given their dependence on external factors that constantly change and evolve.

5. Conclusion

Our objective behind this paper is to make sustainability rating systems available for infrastructure projects. Our approach focuses on the ecological dimension of sustainability with an LCA on a major deep-sea quay construction project on the Island of Heligoland. Our goal is to find the most climatically sound option between a king post wall and four different types of state-of-the-art sheet pile structures. The results from our LCA show that the king post wall is the best planning option with the smallest climatic impact across a service lifetime of 100 years.

More important is that we were successfull in selecting the climatically best planning options for port infrastructure projects. Our LCA approach is hence a first key step towards developing a sustainability rating system for port infrastructure which had generally not been covered by rating systems before despite the enormours potential for environmental optimisation. We have subsequently taken an important step to close this gap.

A holistic and transparent sustainability rating, however, must consider the ecological, economical and socio-functional dimensions of sustainabilty altogether. Having developed an approach to look at the ecological side, our future work towards a full rating system for port infrastructure projects will certainly concentrate on evaluating the other dimensions of sustainability. The next step will be a life cycle cost analysis, given that future decisions on whether realising new infrastructure projects or not will increasingly rely upon their life cycle costs [9].

We are nevertheless convinced that even today, evaluating sustainabilty must become an integral part of planning processes and should play a key role in any comparison of different planning options [11]. Thanks to the approach that we demonstrated, we will specifically encourage our clients and partners for port infrastructure projects and waterway engineering to increasingly discuss and consider sustainability across service lifetimes. It is in our opinion of overriding importance to make infrastructure projects more sustainable in an effort to minimise the sector's adverse environmental effects.

6. Acknowledgements

The authors would like to thank their colleagues at WTM Engineers, and the Heligoland project team in particular, for many useful comments and discussions on port infrastructure projects. We would also like to acknowledge the valuable comments and suggestions of the reviewers, which have improved the quality of this paper. But most of all the authors would like to thank the Government Authority of the island of Heligoland for kindly granting permission to using the southern quay construction project as a case study for our analysis.

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Exemplary Results of the Implementation of the Assessment System BNB in the Public Sector

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Summary

With the introduction of the Guideline for Sustainable Building [1] the Federal Government has enforced an important component of its sustainability strategy in the public sector. In the first step the Federal Building Authorities are obliged by edict to evaluate their buildings, using the Assessment System for Sustainable Buildings (BNB).

As a result of concrete specifications by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), the Guideline for Sustainable Building and the introduced Assessment System for Sustainable Building (BNB) have become the most important tools with which to implement high quality standards in federal construction. With the introduction of the Guideline for Sustainable Building the Federal Government has enforced an important component of its sustainability strategy in the public sector.

The Federal Government plays a model role, especially with gold standard certified buildings, such as the new build Federal Ministry of Education and Research or the Office Building “House 2019” for the Federal Environment Agency in Berlin. The actual task is, to establish good conditions for a broad implementation of the Assessment System BNB into the practical work of the public sector in total. Now other clients, such as the federal states and the local authorities are invited to make use of the BNB-System.

The actual task is, to establish good conditions for a broad implementation of the Assessment System BNB into the practical work of the public sector in total. The intensive specialist exchange between the newly created compliance testing offices and the Department of Sustainable Building achieves quality assurance with respect to the uniform interpretation and application of the BNB and thereby makes a decisive contribution towards implementing sustainable building within federal building authorities. Now other clients, such as the federal states and the local authorities are invited to make use of the BNB-System.

Further result would be considered by the presentation. Further information is carried out with the Information Portal Sustainable Building “www.nachhaltigesbauen.de” of the BMUB.

Keywords: building; guideline; assessment system; strategies; public sector

1. Introduction

According to the national Sustainability Strategy in Germany the Round Table for Sustainable Building was established in 2001, as an advice board for the Federal Building Ministry, and has since then supervised the development of sustainable building on a federal level. The Round Table is constituded of numerous representatives from the building industry, the building materials industry, the Chamber of Architects, the Chamber of Engineers, federal, state and municipal building authorities as well as scientific institutions.

The continuous involvement of the Round Table ensures the further development of sustainable building, with a high level of acceptance within the German building sector. The different working groups of the Round Table make a key contribution to the systematic and content-based development of a uniform national assessment system in Germany, wich also forms the basis of the Assessment System for Sustainable Building (BNB).

Also in 2001 a first Guideline for Sustainable Building was published in 2001. It was made obligatory for the Federal Building Authorities and operate as a practical aid in the planning phase, the construction, the utilisation including the structural maintenance and the modernisation.

In March 2011, a reworked version of the Guideline for Sustainable Building was introduced by the German Federal Building Ministry. Thus the Federal Building Authorities were obliged by edict to evaluate Office and Administration Buildings, using the Assessment System for Sustainable Building (BNB). Using the Assessment System is voluntary for other building authorities, such as Federal States, municipalities or the private sector.

2. Instruments and Tools for the Evaluation of Sustainability

2.1 The Guideline for Sustainable Building

As a result of concrete specifications by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), the Guideline for Sustainable Building and the introduced Assessment System for Sustainable Building (BNB) have become the most important tools with which to implement high quality standards in federal construction. With the introduction of the Guideline for Sustainable Building the Federal Government has enforced an important component of its sustainability strategy in the public sector.

The Guideline for Sustainable Building explains the generally valid principles and methods for sustainable planning, building, opertaion and use of buildings and properties. It thus adresses both, the planning, design and construction as well as the use and operating phase of existing buildings. However, this Guideline also serves as a tool when it comes to considering aspects of sustainability during the entire life cycle of buildings and properties. Therefore the Guideline is broken down into the following parts:

- Part A - Principles of Sustainable Building
- Part B - Sustainable Building Projects
- Part C - Recommendations for the Sustainable Use and Operation of Buildings
- Part D - Refurbishment of Buildings.

The documents needed to implement the Guideline for Sustainable Building are included in Annexe and can be downloaded via the “Information Portal Sustainable Building (www.nachhaltigesbauen.de). These documents include, for instance, the criteria profiles, input data or minimum fulfilment levels for the BNB Assessment System. This concept enables the ongoin updating of the information, tools and other documents which supplement this Guideline and thereby ensures that these documents ar as up to date as possible.

2.2 Instruments and Tools

The The Life Cycle Assessment (LCA) has an important function in the Assessment System for Sustainable Building (BNB). The LCA calculates the environmental impact of factors causing pollution like greenhouse gas, acid rain or the ozone hole. The OKOBAUDAT is an online database, containing quality-checked LCA data sets from the construction sector for all relevant building materials. It is accessible free of charge as part of the Assessment System for Sustainable Building (BNB). It forms the basis for the LCA of buildings. OKOBAUDAT data sets are subject to strict quality criteria and thus allow for reliable conclusions about a building`s ecological quality.

The LCA Tool for Buildings, within the Assessment System for Sustainable Building (BNB), is an easy-to-use tool and has been developed to standardise LCA. It supports the user by complying with the requirements. An editor for creating building elements represents the main feature of eLCA. It allows transparent modelling of building elements. The building element, including its materials, is shown on a dynamic graphic, which enables a visual check of the input values. In addition, an integrated building elements library with typical sample designs facilitates working with the tool. documented.

WECOBIS is part of the sustainable building strategy of the German Government. In the context of sustainable construction as well as in correlation with European and national development of regulations, health and environmental issues of building materials gain increasing importance. A well-considered selection and assessment of construction products is one of the main challenges for sustainable planning, construction and the adjacent facility management of buildings. WECOBIS serves as a useful data base and allows a qualitative assessment of main construction materials and building products. To become more helpful for planners, WECOBIS as well offers especially prepared knowledge for certain purposes, e. g. building product information required for BNB certification. The applicability of the WECOBIS content will be furthermore enhanced by the planning & tendering manual, available in 2015. Furthermore, myWECOBIS will offer new technical functions for more user-friendliness.

3. The Assement System for Sustainable Building

Various research projects, financed under the Research Initiative “Future Building” of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) provided the basis for a research- and planning-based sustainable construction evaluation system for office and administrative buildings, being advanced as “Assessment System for Sustainable Building”.

The System follows an integrated approach of evaluation taking the life cycle of a building into account and carrying out quantifivation according to transparent and comprehensible rules. Evaluation is based in five main groups of criteria of sustainable building: ecological quality, economic quality, sociocultural and functional quality, technical quality and process quality. They are separately assessed, based on currently 45 criteria, grouped thematically into 11 criteria groups. Thus making it possible to identify special qualities on each level.An overall score is calculated, based on the evaluation results and a specific weighting. The location profile, which is influenced by the planning activities only in a limited degree, is mentioned separately. The value of 100 points always corresponds to the target value definition. Parallel to the target value, a reference value of 50 points is defined along with a threshold value of 10 points as the minimum requirement. Compliance with the threshold value must always be documented as part of the process. The assessment of the criteria is summarised in the main criteria groups. In view of the fact that criteria of varying relevance are grouped together, the assessment points achieved are weighted with a significance factor of 1 to 3 (minor to great importance). This is defined for each individual criteria profile. The degree of fulfilment in the main criteria group is calculated from the relationship between the maximum achievable numbers of points and the numbers actually reached. This result is incorporated along with the stipulated weighting into the overall result.Depending on the overall performance, the building can be awarded with a bronze, silver or gold certificate.

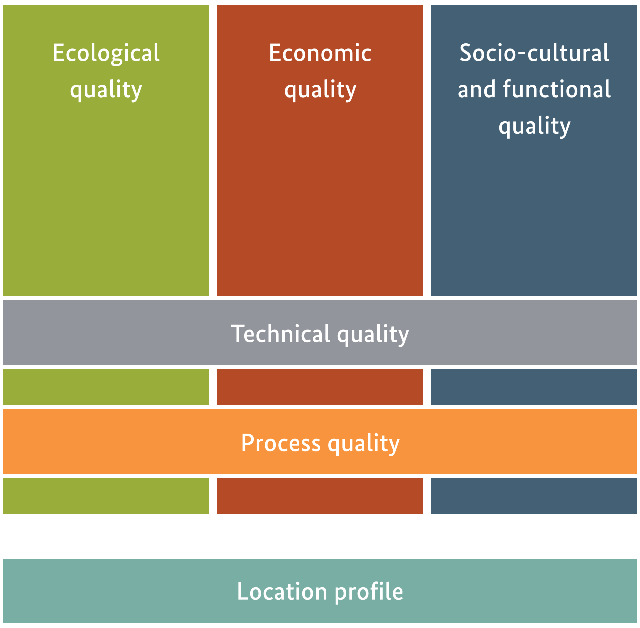

Fig. 1 Assessment System for Sustainable Building - main criteria groups (Source: BBSR)

The Assessment System for Sustainable Building is primarily a planning-based system. The final relevant documentations of conformity are measurements made at the beginning of the utilisation phase for verifying the qualities achieved. As a rule the compilation of documents of conformity requires interdisciplinary collaboration of the involved actors. Nonetheless, main responsibility for individual criteria profiles can be assigned to particular individuals who have primary possession of the relevant information.

4. Implementation of the Sustainability Assessment

4.1 Federal Building Authorities

In the first step the Federal Building Authorities are obliged by edict to evaluate their buildings, using the Assessment System for Sustainable Buildings (BNB). For instance for newly erected office, administration, educational and laboratory buildings with investment costs of € 2 million and above, the appropriate BNB requirements must be applied so that the building quality fulfils the “Silver Standard”. This Standard is going far beyond today’s usual standards in terms of energy efficiency, environmental effects and user comfort, among others. The Federal Government plays a model role, especially with gold standard certified buildings. Ambitious new construction projects such as the Federal Environment Agency and the Federal Ministry of Education and Research (BMBF) in Berlin have already been awarded the highest “Gold Standard” BNB certification. This new office Building of the Federal Environment Agency for about 30 employees at the research location in Berlin-Marienfelde, called UBA 2019, was built as a “Zero Energy Building”. The building fulfilled already the standard required by the European Union for new erected public buildings from 2019 onwards.

Fig. 2 Federal Ministry of Education and Research (Source: BBSR)

The Federal Constitutional Court in Karlsruhe was the first federal building project evaluated with the “Complete Refurbishment” BNB module. Therefore it was a pilot project for this application and it achieved with the silver standard and a score of 1.72 a good result.

4.2 Network for Sustainable Federal Building

Within the Network for Sustainable Federal Building, the BBSR currently brings together around 380 BNB sustainability coordinators from federal and state administrations, as well as the Institute for Federal Real Estate (BImA), thereby creating an internal information and communication platform. The Information Portal for Sustainable Building serves as a forum for discussing and sharing experience gathered in practically applying the BNB, thus promoting further development of sustainable building. The experience gathered while applying the BNB system variants in practice is reflected in the FAQs published in the portal.

One key element of the network is the annual convention for all those who apply the BNB, which is organised by the Department of Sustainable Building. It gives sustainability coordinators the chance to regularly exchange experiences on implementing the guideline and the BNB in the relevant building authorities. The two-day event provides a mixture of plenary lectures, discussion groups and workshops on specific themes, such as contractual design, the introduction of new instruments including electronic Life Cycle Assessment (eLCA) and the concrete study of the building authorities’ practical experiences.

The Network for Sustainable Federal Building is becoming increasingly important with respect to allocating tasks of compliance testing to federal building authorities. The tasks concerning advice and certification for federal building measures, which were assumed by the BBSR until the end of

2014, will be successively taken over during 2015 by the Federal Office for Building and Regional Planning (BBR) and by the offices responsible for technical supervision in the individual states on their own authority.

On this basis, compliance testing for the overhauled and extended Federal Constitutional Court in Karlsruhe was carried out during its award process by the Baden-Württemberg Control Centre for the Sustainable Building of Federal Buildings. The Control Centre was also assigned with compliance testing of federal building authority measures for the BNB use profile “Research and Laboratory Buildings”, to ensure a uniform standard of assessment on a federal level. In coordination with the BBSR, it has already been able to successfully complete compliance testing for four laboratory buildings. The Federal Office for Building and Regional Planning continues to carry out compliance testing for building measures that are implemented on its own account, including for this system variant.

5. Conclusion

The actual task is, to establish good conditions for a broad implementation of the Assessment System BNB into the practical work of the public sector in total. The intensive specialist exchange between the newly created compliance testing offices and the Department of Sustainable Building achieves quality assurance with respect to the uniform interpretation and application of the BNB and thereby makes a decisive contribution towards implementing sustainable building within federal building authorities. Now other clients, such as the federal states and the local authorities are invited to make use of the BNB-System. BNB enables a transparent and objective evaluation of the sustainability of public buildings.

Further result would be considered by the presentation. Further information is carried out with the Information Portal Sustainable Building “www.nachhaltigesbauen.de” of the BMUB.

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Façade design for night cooling by natural ventilation in different climate zones

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Abstract

Depending on the climate region, the local comfort standard and the efficiency of existing building services, the share of energy for cooling, heating and artificial lightning of buildings is between 30% and 50% of the overall final energy consumption of the country. The required energy for cooling of buildings can be significantly reduced by night ventilation. In this case cool air is ventilated through the building to discharge heat energy stored in walls, floor slabs, and furniture. The efficiency of this method depends mainly on the air exchange rate between the outdoor environment and the indoor air volume. Driving forces for the air flow through façade openings are the outside air temperature drop during night, wind pressure distributions acting on the façade due to local wind and the availability of cross wind flow through the building. Resistances for the air flow are given by the size and the geometry of facade openings which can be quantified by discharge coefficients. In the facade design phase the relation between window size and effective opening area must be considered. With predicted discharge coefficients the overall energy efficiency and indoor temperature of buildings with natural ventilation can be analyzed in transient multi zone models. Exemplary buildings in Campinas, Brazil and Hamburg, Germany are analyzed concerning their potential of this method to save energy.

Keywords: energy efficiency, facade opening, discharge coefficient, night cooling, natural ventilation

1. Background

The city of Campinas is located in the Southeast of Brazil with summer average temperatures exceeding 30°C and high relative humidity levels throughout the year. Protection against overheating is one of the most important aspects to be considered in building physics. The city of Hamburg is located in the North of Germany. The moderate climate zone has strongly distinct seasons with cold winter and hot summer days. A thermal insulated building envelope is as important as an intelligent concept to avoid overheating. It is aimed to use the temperature amplitude between day and night in both countries for night ventilation to reduce the cooling loads. Massive concrete elements are heat storages during the day time. For night cooling the heat convection from inside to outside shall be maximized, but it is limited by the air exchange rate.

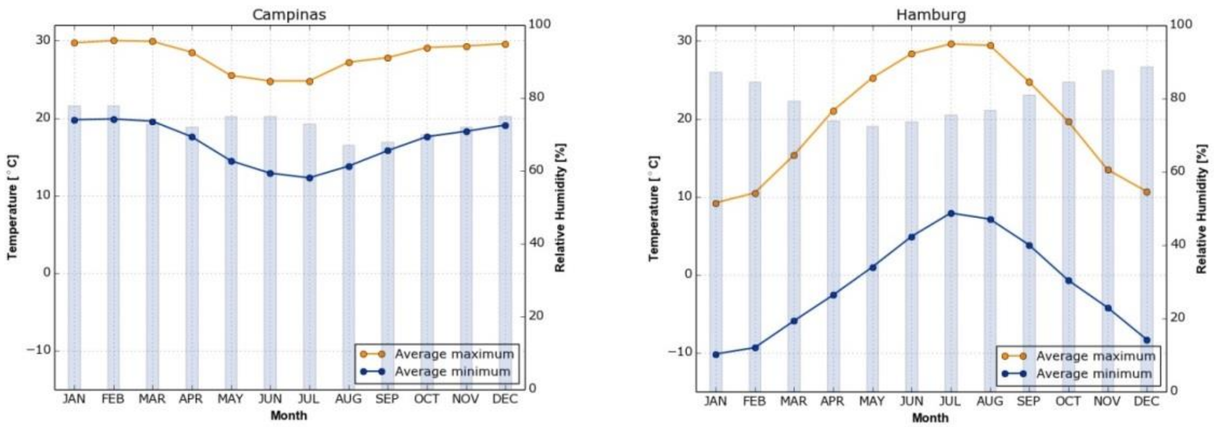


Fig. 1: Weather profile of Campinas, Brazil (left) and Hamburg, Germany (right)

2. Methods

The energy efficiency and indoor temperatures are analyzed with transient multi zone simulations. The thermo-energetic performance using night ventilation in exemplary office rooms of non-residential buildings is simulated with EnergyPlus. EnergyPlus is a building energy simulation program to model energy consumption and water use in buildings. It is a free and open-source software funded by the U.S. Department of Energy (DOE) Building Technologies Office (BTO) and managed by the National Renewable Energy Laboratory (NREL) [1]. The studied rooms are located in Brazil (Campinas) and Germany (Hamburg) in university facilities with typical office activity.

Fig. 2: Southwest view of the campus building IFCH Campinas

Fig. 3: South view of the campus building HafenCity University, Hamburg

The analyzed room in the hot Brazil climate demands the use of air conditioning systems during most hours of the day to provide comfort for the users. Natural night ventilation can be used to reduce the cooling loads. The office room in Germany is naturally ventilated and has no mechanical ventilation. The external shading by the balcony construction shown in figure 3 and 4 in the area of the test room is not considered in the simulations for research purposes. To ensure the user comfort, the hours of overheating shall be minimized. According to national German standards [2], the maximum comfort temperature is 26°C. Generally the amount of overheating can be quantified by different methods. Just counting the number of hours above 26°C would be insufficient for the reason that the user comfort decreases with raising temperature. Therefore it is common to consider the delta to the maximum comfort temperature. An appropriate and simple method to use is to determine the energy consumption of an imaginary air conditioning system that cools the room temperature to 26°C if required. Hourly local weather data are used for both entire year simulations. The thermal loads are given by internal gains from occupancy, equipment and lighting systems. Air flow resistances by openings for passive ventilation modes are taken from the literature and adjusted for use in each façade. Details about each room as well as modeling settings are presented in Table 1.

Table 1 - Details about the rooms

		Unicamp - IFCH Campinas/SP, Brazil	**HafenCity University Hamburg, Germany**
Use		Office Mo - Fr 9 a.m. – 5 p.m.	Office Mo - Fr 8 a.m. – 7 p.m.
Floor Area		29.4 m²	40.1 m²
Internal Gains			
People	number	3	4
	activity level [3]	130 W	130 W
	heat gain	13.3 W/m²	13.0 W/m²
	fraction radiant [3]	0.58	0.58
	sensible heat fraction [3]	0.58	0.58
Lights		13.0 W/m²	7.4 W/m²
Equipment		12.1 W/m²	15.0 W/m²

Temperature Limits		25°C HVAC (PTAC) COP 2.11W/W during working hours	26°C Natural ventilation only
Window Glass Area (see also table 2)		5.14 m² single glazing	15.44 m² triple glazing
Openable Area		2.68 m² Horizontally pivoted	2.30 m² Bottom pivoted
Discharge Coefficient c_d		0.61	0.61
Opening Factor		0.12	0.458
Orientation		North-East	South
Shading		Blinds and external fixed side elements	Blinds max. 180° close above 300 W/m²
Natural Ventilation modes	Base	"No Natural Ventilation"	"No Natural Ventilation"
	Vent 1	"Static Night Cooling" Night Ventilation from 9 p.m. until 9 a.m.	"Static Night Cooling" Night ventilation from 7 p.m. until 8 a.m.
	Vent 2	"Selective Ventilation" Natural Ventilation when $T_{in} > T_{out}$ and $T_{in} > 24°C$	"Selective Ventilation" Natural ventilation when $T_{in} > T_{out}$ and $T_{in} > T_{set}$ $T_{set} = 21°C$ when occupancy, else 18°C

3. Natural Ventilation Simulation in EnergyPlus

This research addresses a method to quantify relevant characteristics of façade design relative to its suitability for natural nocturnal ventilation. Hence, two different ventilation strategies are analyzed for both rooms described in Table 1. The static night cooling allows natural ventilation during the night independently of the outdoor air temperature. This method is easy to implement in existing, motorized windows and there is no need for complex façade control software. Additionally, a selective ventilation mode is simulated. This mode allows natural ventilation during the day, especially during early daytime, as well as during the night, if the room air temperature is above the outdoor air temperature and the room temperature is above a temperature setpoint. This setpoint will be chosen by local climate conditions (Table 1).

Beside the ventilation strategy, the performance of natural ventilation depends on the design of the airflow path. Changes in geometry and friction among the airflow path are the most significant flow resistances. In energy simulation tools (e.g. EnergyPlus) these resistances are often summarized to discharge coefficients c_d which indicate the effectiveness of airflow though openings. For rectangular openings, e.g. 90 degrees open windows, the resistance coefficient $\zeta = 1/c_d$ is in a small range between 2.7 and 2.8 [4] and therefore the discharge coefficient is 0.61. For common used window constructions the obstruction of the pane in pivoted cases must also be considered. The tilted pane reduces the effective area Aeff which is available for the airflow. Consequently it is not sufficient to use the discharge coefficient $c_d = 0.61$ to describe all impacts. Bottom pivoted windows are used at the HafenCity University in Germany (Figure 4, right). Hult et al. [5] studied the algorithm used by EnergyPlus for pivoted windows and modified the expression in order to achieve better results for top pivoted windows. For this study the expression is transformed for the calculation of Aeff for bottom pivoted windows to take the different position of the rotating axis into account. W/H is the window width/height, α is the opening angle and z is the vertical coordinate starting from the pivoting axis. The effective window area for the window system in Hamburg is calculated according to the equations (1) and (2):

$$A_{eff} = \int_{0}^{H\cos(\alpha)} W_{pivot}(z)\,dz + \int_{H\cos(\alpha)}^{H} W dz \qquad (1)$$

$$W_{pivot} = \left(\frac{1}{W^2} + \frac{1}{(2\,z\,\tan(\alpha) + \sin(\alpha)W)^2}\right)^{-0.5} \qquad (2)$$

The IFCH building in Brazil has horizontally pivoted windows where the rotation axis is eccentrically placed (Figure 4, left). There is no reliable reference available for this window construction. Geometric analysis provides opening factors equivalent for the ratio of effective and geometric opening area. The effective area for ventilation is the rectangular area which remains open when the pane is tilted (Figure 5). The lateral areas for ventilation of the windows are not considered as they are obstructed by shading elements. The ratio between the effective area and the opening area resulted in an opening factor of 0.12 (Table 1).

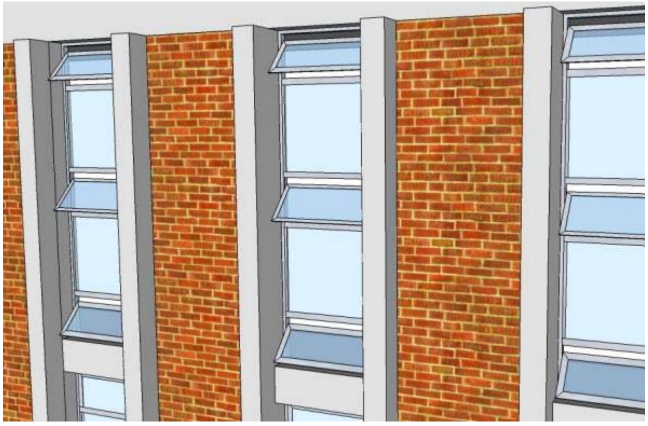
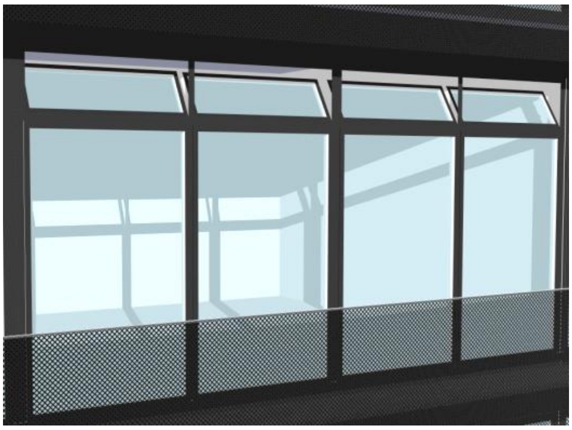



Fig. 4: Illustration of the openings for ventilation of IFCH Campinas (left) and HafenCity University, Hamburg (right)

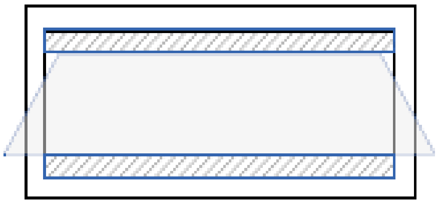


Fig. 5: Effective area for ventilation that is considered in IFCH building

The thermal properties of the envelope are also important for the effectiveness of the natural ventilation, as an additional thermal load is transmitted through the envelope and needs to be removed by natural or artificial ways. Table 2 shows the thermal properties of the envelope for both buildings.

Table 2 - Thermal properties of the components of the model

	Component	U-factor (W/(m².K))	SHGC [-]
IFCH Campinas	External wall 1	2.65	
	External wall 2	3.09	
	Slab	2.04	
	Roof	1.74	
	Single glazing	3.84	0.818
HafenCity University	Triple glazing	0.60	0.450
	Internal walls and slabs	adiabatic	

4. Results and Discussion

4.1 Energy consumption

An overview of the monthly energy consumption for cooling of both rooms is presented and discussed for further analysis. From figure 6 it is possible to note that night ventilation for the Brazilian building (IFCH) is not that efficient from energy aspects considering the whole year. Evaluating the peak of cooling in October, natural ventilation allows reductions of the cooling load up to 14% (Table 3). Furthermore in winter, the strategy was more efficient reducing up to 29% of the cooling energy in July. The consumption during this season is not expressive; therefore it gives no big contribution to the annual energy demand (reductions around 6%). On the opposite, significant reductions are possible for the room in Hamburg (HCU), mainly with selective ventilation. The potential reduction reaches up to 87% percent in July through selective ventilation and 23% in times with peak cooling loads. Yearly it is possible to reduce 76% of the cooling demand with night ventilation and 93% with selective ventilation (Figure 7).

In general it is found that natural ventilation is an effective method to reduce the energy consumption for cooling as well as the peak loads. In moderate climate with cooler nighttime air temperatures the efficiency is also driven by the ventilation strategy. An adaptive opening control allows the usage of temperature difference between indoor and outdoor for passive cooling but it can also prevent the room against overheating, while the static ventilation does not consider the outdoor temperature. In hot climates the positive effect of natural ventilation is less noticeable. For the case of static night cooling an energy conservation of 6% is calculated. For the flexible ventilation strategy based on the temperature difference the same energy conservation percentage of 6% is calculated. A higher benefit for a flexible ventilation strategy cannot be determined because the windows are open less frequently.

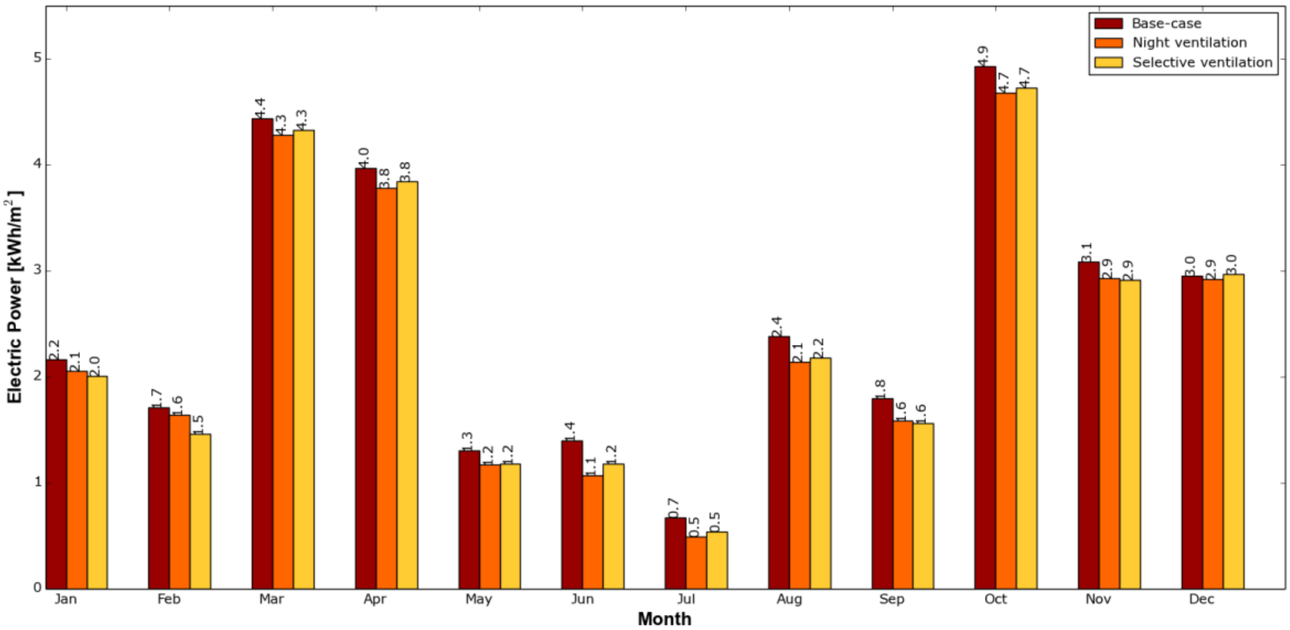


Fig. 6: Monthly air conditioning use for the room in Campinas

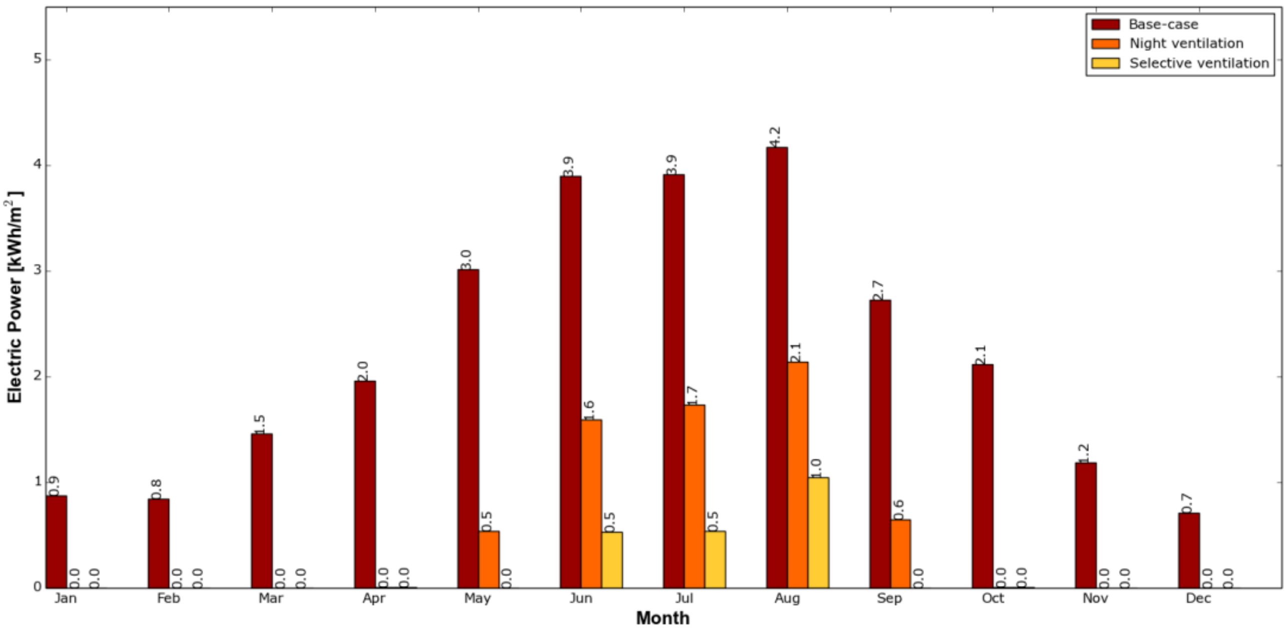


Fig. 7: Monthly air conditioning use for the room in Hamburg

Table 3 - Peak cooling sensible heat gain.

	HVAC input sensible air cooling (kW) and date + time of the peak load		
Room	Base-case	Night ventilation	Selective ventilation
HCU	-1.87 08/03 15:00	-1.60 08/03 15:10	-1.45 08/07 15:10
IFCH	-4.87 10/13 09:03	-4.20 10/12 09:03	-4.21 10/12 09:03

4.2 Temperature profile

According to the weather profile of Campinas, the highest outdoor temperatures occur between January and February. Analyzing the temperature during working hours, better results were found when using passive strategies in January 16th. Therefore this was the period to be analyzed for summer conditions (Figure 8, left). The same criterion is adopted for the climate of Hamburg. Better results are achieved with natural ventilation exemplary in July 9th.

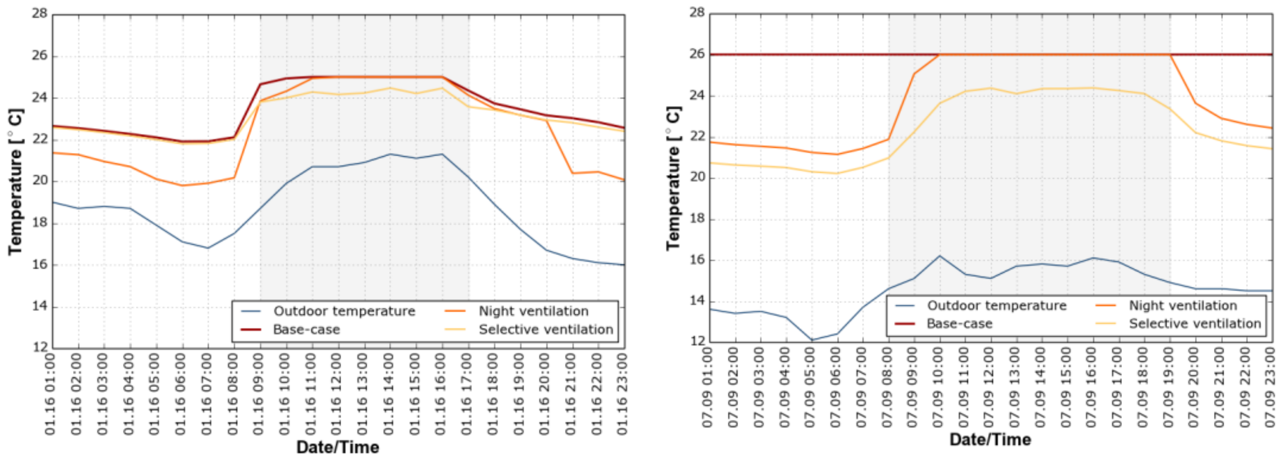


Fig. 8: Indoor temperatures during occupation of the rooms in summer for the three cases in Campinas, January 16th (on the left) and Hamburg, July 9th (on the right).

The temperature behavior demonstrates the need of natural ventilation for energy efficient buildings in Hamburg. With only night ventilation the room air temperature will be the same as the defined cooling temperature setpoint due to high thermal insulation of the university building in Hamburg which prevents thermal losses. The idea of static night cooling is a simple window opening control algorithm to use natural ventilation during the night in a predefined time interval. During the day the windows are closed to prevent the room against overheating on hot days. For moderate outdoor temperatures as shown in figure 8 right, the use of natural ventilation the whole day long will decrease indoor temperatures without energy consumption for air conditioning. The discharge coefficient c_d and the effective area for ventilation A_{eff} of windows are limiting factors for the air exchange rate. When the heat losses by infiltration are lower than the internal gains, high indoor temperatures will occur even with moderate outdoor temperatures.

For retrofitting the room of the HafenCity University Hamburg the ventilation cross section area shall be increased in order to obtain higher air exchange rates. Heat convection from indoor to outdoor will increase.

The use of natural ventilation does not bring significant contributions on reducing indoor temperatures for the room in Brazil. One reason is the small difference between indoor and outdoor temperatures during the night. The glazing area is also an important contributor for heat gains as it can be seen in the next section. In Brazil, the single glazing causes heat transmission during the night. As a result, for hot climate conditions the retrofitting strategy should consider additional aspects besides nighttime natural air ventilation.

4.3 Sensible heat

Heat dissipation occurs mainly through air conditioning (during the day in all cases), opaque surfaces (probably during the night) and infiltration (in the ventilated cases). During the night, for the base-case (without natural ventilation) the main way to dissipate heat is by conduction through opaque and transparent surfaces. For the natural ventilated cases the main way becomes infiltration, decreasing the heat removal by conduction through surfaces. In all cases the indoor temperature during the night is much higher than the outdoors, what leads to high rates of heat either by conduction through opaque surfaces or air exchange through infiltration.

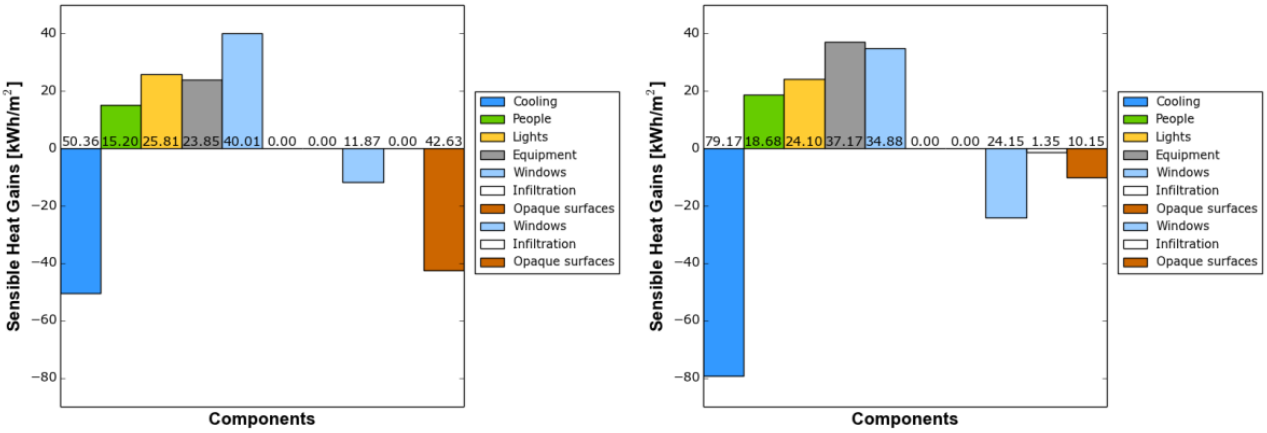


Fig. 9: Annual heat gains of the room for the base-cases in Campinas (a) and in Hamburg (b)

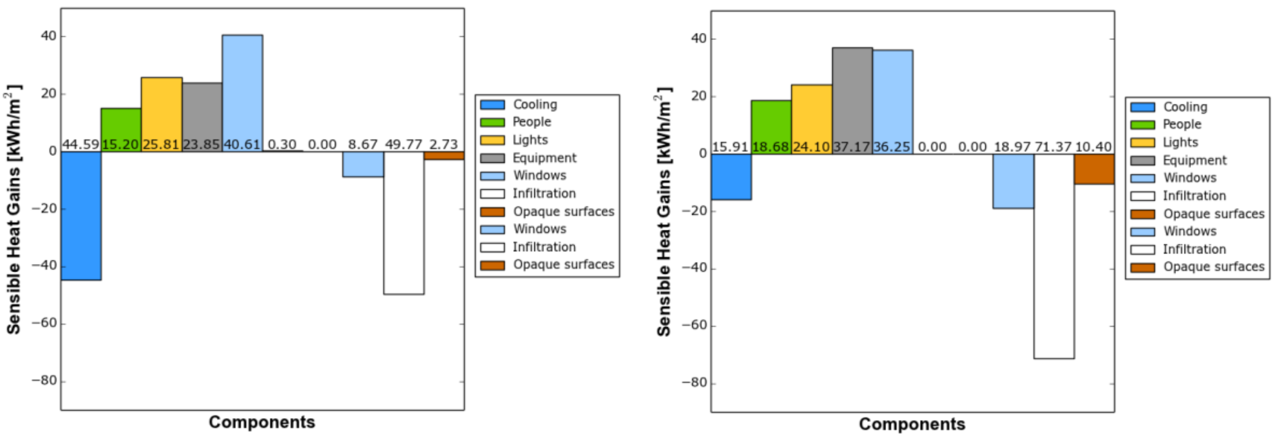
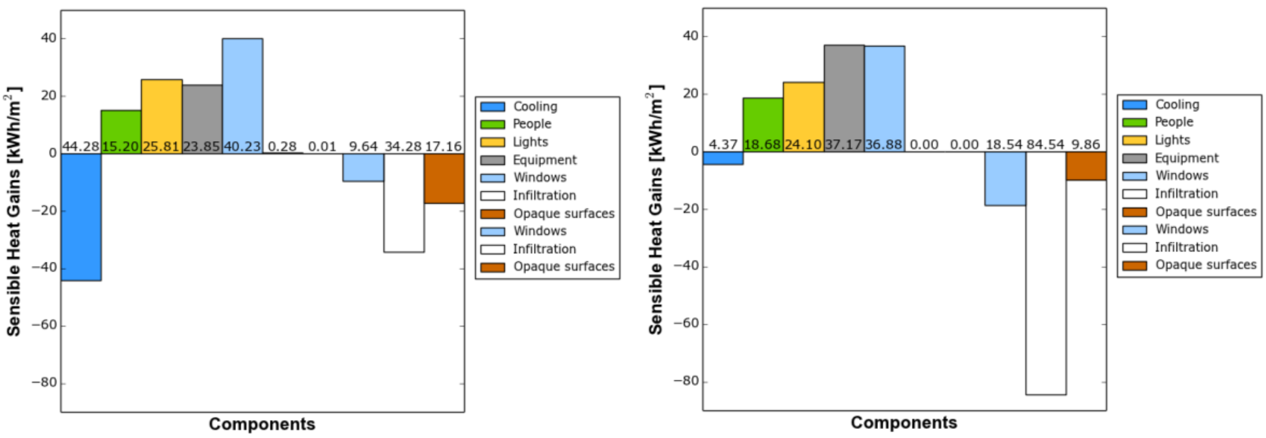


Fig. 10: Annual heat gains of the room for night ventilation in Campinas (a) and in Hamburg (b)



5. Conclusions

The use of natural ventilation for summer night cooling is an efficient method either for reducing indoor temperatures, increasing energy conservation and air quality. Besides local climate conditions the design of window openings is a key factor for natural ventilation.
Static night cooling (windows are open in a defined time period) decreases the energy consumption for air conditioning in both countries. Night cooling in Brazil was not as effective as in Hamburg, as the air temperature drop by night is lower. An intelligent facade controlled by the difference of temperature between outdoors and indoors to allow natural ventilation for cooling when needed can further noticeably reduce the energy consumption in moderate climate regions like Germany. Dynamic simulations of airflow should consider an appropriate description of the window geometry (discharge coefficient, effective area for ventilation) in order to reduce the uncertainty of the model. The study demonstrates the application of a model to represent bottom pivoted windows (Hamburg) and a simplified approach for horizontal eccentric pivoted windows with lateral barriers (Campinas).

6. Outlook

For the verification of the above used air flow resistance data (discharge coefficient, effective area) a joint research project will start in 12-2015. To determine discharge coefficients for commonly used window systems (bottom pivoted, side pivoted) wind tunnel test with these window types will be done at the laboratory of the State University of Campinas, Brazil. Additional tracer gas measurements with these window systems will be done at the façade test laboratory of the HafenCity University Hamburg, Germany. Based on these tests computational fluid dynamic (CFD) models can be verified and the field of window systems can be extended by a numerical parameter study. In the next project step the energetic and comfort performance of typical buildings with natural ventilation will be analyzed by EnergyPlus to develop design nomograms for the prediction of the air exchange rate in buildings by natural ventilation. Recommendations for the geometry of the window openings with maximum discharge coefficients can be given based on the successive testing and numerical analysis.

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Faithfulness in small things?

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Summary

Looking at the individual decisions made in a municipal school project some aspects are shown that lead to more sustainability – or just the opposite.

Keywords: public-sector constructions, educational constructions, project management

1. Sustaining project flow

"Sustainability of new buildings as well as of existing buildings needs visions, concepts, planning and financing, above all, however, a day-to-day implementation!" [1, p.118]. In the opinion of the author of this paper this day-to-day approach does not only apply to large projects with a view to public appeal (which is often published in relevant architecture magazines) but also to much smaller construction projects. Concerning these smaller projects, public authorities should lead the way. The following construction project that could have been realized in any municipality, will be outlined here as an example from real life.

The text provided represents a school but the exact whereabouts are irrelevant. In the following sections different stations are described and commented on according to the main idea of sustainable construction; i.e. responsible use of resources of all kind.

2. The Hans-Carl-von-Carlowitz School in Unterschilda

2.1 Initial position

The Hans-Carl-von-Carlowith school is located in one of the districts of Unterschilda. Officially the principal here calls the shots; the caretaker, however, was the actual landlord. He used to live at the school and knew the building like the back of his hand. His omnipresence and authority nipped all vandalism in the bud. He was very attentive and skilled at the same time and mended even small damages immediately, so that it was rare that external craftsmen needed to be asked to do repairs.

2.2 Municipal reduction of costs since May 2004

After the caretaker retired from work, the municipality of Schilda decided for financial reasons not to fill the vacancy. Instead, a colleague from the nearby school was instructed to see to the school's needs and to do this when he dropped by once in a while. The caretaker´s house – the principal intervened – was finally used as the props room for the theatre equipment belonging to the school.

At the same time, the municipality decided to downsize the communal building department both in size and also concerning human resources [2, p. 39]. Older staff was sent into early retirement and old reference documentations were put through the shredder [1, p. 237]. Rented offices and archive rooms that put an unnecessary strain on the budget became vacant.

2.3 Small, inexplicable changes

Regular schooling carried on as usual. However there were “creeping” changes. Graffiti on restroom doors was on the agenda every day; “woodcarving” on furniture was standard. Moreover, two windows could not be closed in the crafts room [3, p. 208ff], which was rather unfortuante as rainwater was pouring down the facade [4, p. 202 ff]. After all, it was not possible for the part-time caretaker to clean drain pipes due to his tight time table. He needed all his time to organize and instruct craftsmen for the repairwork on larger damages.

2.4 The blow-off

Hall monitoring is not popular. Neither with teachers, who are in charge of hall monitoring duty, nor with students. After a short time, the students chose the overgrown garden behind the caretaker’s house as being a “teacher-free zone”. On bad weather days they could even enter the house through the window – provided the students of the theatre project were smart enough to leave the windows open.

In December 2006, however, these convenient circumstances came to an abrupt end as smouldering cigarette ends ignited the paper maché decoration from the last performance of “The physicists” [2, p. 106]. But not enough: two gas bottles that had not been used during the last summer barbecue exploded in the house [3, p. 142 ff]. By the time the fire brigade arrived, the props rooms were long gone.

2.5 Restoration of the school – first act

In order to prevent the flames from spreading to the school building, the fire brigade extinguished the fire with tons of water [5, p. 299], which poured down a light well and flooded the archives in the basement of the school building. This, however, was only noticed shortly after the Christmas holidays [5, p. 303].

As a result of the fire, a pollutant clean-up of the caretaker's home was necessary. Alert parents demanded the pollutant analysis to be carried out in the other rooms of the school building, especially the basement which had previously been flooded. The pollutants that were found under the floor covering [5 p. 410 ff] didn't surprise the experts at all and were no reason for panic from their point of view. Nevertheless, parents and school management demanded an immediate renovation.

As the building department did not dispose of the necessary resources to carry out this work but the renovation was needed urgently, the caretaker of the neighbouring school was entrusted with the coordination of the work. A company, the manager of which was well acquainted with the town council, presented a favourable offer for an overall renovation (cf. [3, p. 48 ff + 126 ff]) and was finally entrusted with the work. Apart from the planning [3, p. 72], this overall performance included cleaning and painting of the sooty facades [6, p. 290 ff], which improved the visual impression of the building considerably and was praised by all at the summer celebration in 2006.

As the heating expenses had increased significantly during the past years [1, p. 17], some rooms in the basement were insulated on that occasion. The drywall shell that was built-in by the municipal workers on their own initiative [2, p. 39] reduced the size of the room but this was a cheap and quick alternative [6, p. 275]. The basement was now bright and comfortable.

2.6 Endurance test during schooling

However, the good condition did not last long. The drywall shell in the basement got damaged when the children played football and vandalism by teenagers did the rest. Besides that, mould began to cover the shell starting from the window soffits [3, p. 135] and corners [6, p. 275].

The winter weather affected both the new EIFS facade and the freshly painted walls of the school building. The facade was soon covered with algae at the northern part of the building [6, p. 290 ff]. The neighbouring building became dark and greenish and showed irregular bright dots [5, p. 115].

The mould in the basement returned despite comprehensive painting – only the summer season seemed to be trouble-free. However, when in winter 2007 large areas of mould again occurred in the basement as well as damages due to growing vandalism, calls were made for general renovation.

2.7 Renovation of the school building – second act

2.7.1 Elections

This call found attentive ears, as municipal elections were coming up, and – as everyone knows – the commitment to children and education usually goes down well. After the elections, politically active teachers and parents approached the responsible person and insisted on them living up to their promises.

Even though the budget was burdened by increased heating and maintenance costs, a majority of people involved accepted the renovation of the Hans-Carl-von-Carlowitz-School. The key argument was the promise of lower heating and maintenance costs that would arise after the building had been renovated.

2.7.2 Architects

The city council members were very confused when the school treasurer informed them that the architect who was normally assigned would not be entrusted with the redevelopment project but that these services would be subject to tendering. The invitation to tender was finally issued by the building authority, which of course assumed the project lead and management.

Subsequently the contract was awarded to an architectural office with great experience in the area of school building which was located in a major city 250 km away from Schilda. The council mentioned the prospect of follow-up jobs and therefore was granted a significant fee reduction [7, p. 12]. Moreover, the council agreed that some services must not be provided by the architectural office but by the building authority itself [7, p. 5].

2.7.3 Planning I

The enthusiasm experienced a first setback when it became known that only the old building permit files existed, the content of which only partly corresponded with the conditions of the school building [2, p. 110 ff]. Even for the caretaker's house, which had been renovated recently, there were no documents available apart from invoices that had been settled completely by the general contractor [3, p. 172 ff].

In order to guarantee the success of the general renovation, the users of the building were involved in the planning. As a time-saving measure, the architects were required to coordinate directly with the users of the school building [8, p.7] about the objectives of the renovation in joint meetings every other week, at the end of which a new plan should be presented. After a period of one year´s intensive work, and only little support by the building authority which was drowning in work [7, p. 17], the paper was finally presented. It was not possible to meet all the wishes and requirements in the existing building, but due so some extensive reconstruction and new additional constructions in different variants [7, p. 27] these were met at least in part. The concept led to high expectations for the users (“when will it be done?”) and to dismay and reproaches for the building owner faced ewith estimated costs of around 50 million Euro [2, p. 39].

2.7.4 Planning II

Not only the price for the renovation exceeded the budget [9, p. 49], which was only mentioned verbally [8, p. 7], but also the financial situation of Schilda had changed dramatically due to the economic crisis in 2008. After some back and forth at the municipal level the decision was taken that the architects should provide a plan for a sustainable and energy-efficient renovation, the price of which should be only half as much [9, p. 75].

The conceptual design had to be completely redone [3, p. 103ff] – this was also the opinion of the school management. The principal, who had only recently asssumed the office, intended to implement a completely different and modern educational model. Therefore, spacious hallways were needed and a canteen with a kitchen was required as the school offered a full-day supervision for the children [9, p. 68].

These and other requests were taken into consideration in the further development of the renovation plan during 2010. This time, the municipal building authorities were involved more comprehensively – however, they got in trouble more and more at the same time: the cost requirements given by the city council were definitely too tight for the intended measures. At the same time the necessity of measures in view of the deteriorating condition of the building and the expectations of teachers and parents were extremely high.

Fortunately, an additional funding pool was found [2, p. 204 ff] [1, p. 201 ff] so that an amount of at least 35 million Euro was available. This financial support, however, was subject to different requirements [3, p. 166], which could hardly be met taking into account the planned measurements of energy saving for the existing building.

2.7.5 Planning III

The result of all this was that rather than talking about the renovation discussed since 2012 a replacement building was discussed and finally decided on. In order avoid downsizing the number of teachers or students or housing them in the vacant Baron-Münchhausen-School during the construction stage, the responsible persons decided to put up the new building right next to the existing building. Unfortunately, this meant that several very old trees had to be cut down [6, p. 05].

Meanwhile the reproach for inactivity grew louder. Apart from the structural measures at the Hans-Carl-von-Carlowitz-School in 2006, nothing had happened after all. Therefore, individual measures with public appeal should now be advanced [8, p. 9] [9, p. 94].

At the beginning of 2014, many trees were cut down and the former caretaker's house demolished in order to provide the area for the new buildings, the plans for which were far from completion. The construction planning was to be carried out at that time.

2.7.6 Start of construction works

As the caretaker's house had been renovated a few years ago, there was no reason to carry out any analysis of the existing construction [7, p. 23]. Therefore, it was quite a surprise for all that the company who was carrying out the work found considerable contamination of the building [5, p. 420 ff] and subsequently submitted an amendment [7, p. 25]. As a result of this the respective subsidiary of the general contractor [2, p. 164, 167 ff], which carried out the renovation in 2006, filed for insolvency.

It did not come as a surprise that the city council decided [2, p. 170 ff] to no longer entrust municipal staff with the project management but to engage an external partner. The external partner would be cheaper anyway and the responsibility would no longer rest with the council's own employees [7, p. 41] [2, p. 38].

2.7.7 … to be continued

The external partner is still learning the ropes and plans are being redesigned continuously. However, these are only two reasons for the delayed progress of the project so that it could not be presented in this paper.

3. Comment on project progression

The reader who is experienced with public-building projects may have recognized the one or more issue, maybe he or she has had similar experiences. The less experienced reader also may wonder what all this has got to do with sustainability.

“What´s wrong here? - Nearly everything is wrong!” [2, p. 139]. This quotation, taken from a different context, could probably also apply to several aspects of sustainability, e.g.:

- Missing building maintenance. Due to the cutting back of the caretaker position, considerably higher structural costs arose and a school building changed from a cultivated public property into an expensive “demolition building” within a few years only, mainly due to preventable vandalism [10, p. 125] and incorrect user behaviour [1, p. 233].
- Hasty assignment of the first renovation to a general contractor [8, p. 9], although it is known that such an approach usually results in loss of quality (in this case: incomplete pollutant clean-up) [2, p. 39] and simultaneously increasing costs [7, p. 13].
- Lack of competence of the public building owner due to downsizing the number of municipal experts [2, p. 39] and destruction of valuable documents [1, p. 237].
- Waiving professional expertise, planning and invitation to tender, in this case exemplary waiver of the moisture barrier for the internal insulation with disastrous consequences (mould).
- Short-term thinking instead of long-term thinking, not only as far as cost reductions are concerned [1, p. 37 + 237]. For example: the caretaker's home was (non-professionally) renovated and finally demolished. Therefore the premise: “First repair and then replacement” [1, p. 59] has been ignored.
- No appreciation of the existing building [11, p. 3], although the value of the so-called embodied energy should be already known.
- Unnecessary delay of the project by the lack of clearly defined objectives [9, p. 5].

“No doubt, lots of other possible sources of errors could be found.” [9, p. 95] This list demonstrates that sustainability is not only the result of a complex software calculation. It is much more a matter of basic attitude, which manifests itself in numerous details when it comes to construction – or just the opposite, as shown in this example.

4. Finale

4.1 Fiction or truth?

Those who look up the sources of this paper will realize that both the Hans-Carl-von-Carlowitz-School and the town called Schilda do not exist. The attentive German reader has possibly guessed this anyway, as “Schilda” is a notional place in German literature.

It goes without saying not to talk about inside stories [3, p. 160] especially concerning public projects for which architects and structural engineers have to manage and hold taxpayer´s money in trust and political aspects have to be taken into account. However, in light of the rich literature, there is no need to do so anyway.

The project described is completely fictitious, although it has been compiled from various occurrences which took place similarly to the way pictured. The author of this publication adapted the events to the conditions of a school, which could have been any other municipal facility as well. Instead of the timbered house, the caretaker's house exploded [3. p. 142]. The damage from moisture, due to insufficient maintenance of a barn [3, p. 208], changed to moisture damages in the crafts room, a tax advantage changed into demand-specific financial support [3, p. 166], the revision of traffic construction [9, p. 68] to a new educational concept and, finally, the failed repair of the castle [4, p. 174 ff] into that of a basement floor of a school, and so on.

4.2 Just fiction?

Parts of the literature used for this publication have been published some years ago. It would be easy to find further and even older examples for the wasteful use of resources.

Valuable resources include not only heating or cooling energy and recurrent operating costs but also energy already used, the so-called embodied energy of existing buildings, and last but not least the expertise of experienced, public employees who are not eager to turn a quick profit.

The long-lasting relevance of all these issues is proven by the fact that scientific literature has plenty of examples dealing with short-term and erroneous thinking (e.g. [9]) rather than describing successful projects of sustainability in the building industry.

At the same time, this publication shows the failure to learn from mistakes of the past years and decades. It is not fiction but harsh reality that, despite public statements to the contrary, long-term thinking is still sacrificed to short-term aims not only concerning large projects but also for the large number of smaller buildings projects [8, p. 37].

5. Discussion

5.1 „Everything has already been said, but not yet by everyone“

Is this quotation from Karl Valentin applicable to sustainable building? Is this publication merely a repetition of facts only slightly modified that are well known among experts?

The answer is both yes and no:

Yes. On the one hand all issues have been known for years, e.g. that also the customer should have technical expertise [12, p. 11], that the price to pay for a putative cutback in building maintenance is rather high and that unclearly defined objectives result in delay and additional costs [9, p. 49].

And No: On the other hand this publication is an update of the issue [8, p. 4] with the strong interest to demonstrate selected aspects by negative overstatement and so to recall the meaning of some basic principles. Especially in light of increasing specialisation, in part already during the course of studies at university, nowadays the risk of getting lost in the process and neglecting important core competencies is constantly growing (cf. [13]).

Although it is important that beginners and professionally experienced people deal with e.g. sustainability certificates, it is of vital importance for permanent sustainability that all parties involved in the project dispose of fundamental knowledge and competencies in the field of construction work [14], especially with regard to the design and construction in existing contexts [11, p. 3] instead of just “energy-concept pictures”.

5.2 Conclusion

Technical quality as well as process quality are both aspects of sustainable construction [15, p. 18] and have the disadvantage of being only poorly measurable and countable components. Besides, they depend on factors that are subject to only indirect influence as e.g. weather conditions when concreting. An even greater challenge is to deal with existing buildings and the evaluation concerning sustainability.

“Each reasonable further use of existing buildings increases the sustainability use of available assets, avoids costs for a demolition and new buildings and thus is a logical contribution to a resource-saving economy.” [11, p. 3]

In the interest of a resource-friendly use of the available resources, the emphasis should be on further use, renovation and modernisation rather than on demolition and new construction. “In view of the fact … that lots of existing buildings … are the larger part of public … assets, `design and construction in existing contexts´ is more than ever the need of the hour.” [11, p. 3] This is not by far the norm everywhere yet, as it requires a leap: “Real estate strategies … of public authorities have to be … developed and carried out sustainably. This should be done across all parties and election periods for the collective good of future generations.” [1, p. 37]

But this means a considerable change in mentality and an awareness of the value of existing buildings not only from an energetic perspective, but also a change of the teaching at university [1 p. 243] [14]. It also depends on the respective decisions and competencies of all responsible parties, provided that sustainability is more than mere lip service and not only “an often used alibi commonplace”. [10, p.69]

“However important sustainable new buildings are – energy efficiency and sustainability is much more important with respect to existing buildings” [1, p. 228]. To handle this, the focus needs to be on new or just traditional [10, p. 67] sustainable thinking, especially for the large number of smaller private and public construction tasks today.

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Functional building surfaces - Self-sufficient facade module

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Summary

The focus of the research lies on development of a more changeable highly adaptable active self-sufficient facade module, constructed from glass louvers. The advantage of the facade module lies in the self-sufficient regulation of the interior climate. In the case of refurbishment a high user comfort is reached by a minor intervention in the existing building facade - a resource efficient way of refurbishment.
The adaptability facade module is carried out nearly appropriate for circulation of materials. The development is checked by a parametric life cycle analysis. The facade acts as a building cover and provides cold weather protection, amongst other functions. The single-pane glass louver takes over active functions, for example passive energy gain, protection against burglary, and / or screening while fulfilling architectural demands.
FGL control the louvers in the load case temperature and work self-sufficient. The control of the load case CO_2 concentration of the room and from the load case precipitation occurs about the energy entry from the louver covered with photovoltaic and the storage in the frame.

Keywords: parametric life cycle analysis, form memory alloys, self-sufficient air-conditioning, self-sufficient energy supply

1. Introduction

In Germany approx. 40% of the energy is used in the building sector [1]. According to the study of the Ministry for the Environment Safety [2] two trends are recognizable for building: on the one hand more construction in inner cities, on the other hand flexibility of the continuance building. An in future strengthen internal-urban construction which is marked by constant changes arises from it.
The focus of the research projects lies on the development of an adaptable, active, self-sufficient facade module, based on glass louver. The advantage of the facade module lies in the self-sufficient regulation of the space climate. In the case of refurbishment, e. g.for schoolbuildings, a high user comfort is reached with a minor intervention in the existing building facade and therefore a resource efficient renovation is made possible.
The adaptability in buildings is demanded by the constant users' changes. These necessary changes should be carried out suitable for recycling and sustainable. The sustainable chance is calculated using a parametric life cycle analysis. The facade acts as a building cover and provides

cold weather protection, amongst other functions. The single-pane glass louvers take over active functions, for example passive energy gain, burglary protection, and / or screening while fulfilling architectural demands. The control of the louvers in the load case temperature works with form memory alloys and the functions are self-sufficiently and noiselessly. The sensor-based control of the louvers dependents on the CO_2 concentration and on the precipitation and is powered by the energy entry from the photovoltaic louver and the energy storage within the frame.

2. Research objectives

The sustainability of a construction is mainly influenced by the adaptability and reduction in the material circulation. The building facade takes up 17% of the energy consumption of the building sector [3]. This presents itself worldwide alike and shows a big saving potential in this sector and the need of the development of sustainable building facade.

The research aim is to develop an adaptable, active and self-sufficient facade module. Within this facade module four innovations are united:
1 The frame becomes an energy storage.
2 The glass takes over several and additional new functions at the same time.
3 The control and regulation is extended, among the rest, with adaptive form memory alloys.
4 The facade module supplies itself self-sufficiently with energy

A new louver module should be developed. The uppermost or also other louvers are covered with photovoltaic cells. Because photovoltaic still isn´t in use in this dimension, a suitable module is to be investigated, to lay out and to construct. The photovoltaic louver delivers the energy which is stored in the frame. The principle of the louver construction offers favourably conditions for the changeability of the single louver. The newly to be developed storage base on silicon ion is integrated into the frame and remains room-sided interchangeable and therefore changeably. For this the frame construction, a rope pressure profil, must be renewed. e. g. , phase change material (PCM) permits the exchange of the storage with future storage media the changeability. The advantages of the available frame, ease and handling should be received.

The louver of photovoltaic is separately steered. The louver below the sector of photovoltaic can be covered according to the user's wishes. The aim of the plan is to integrate new functions into the glass facade. Knowledge from parallel researches from thermochrome glasses and to ultralight safety glass (glass, polyurethane and polycarbonat) flow onto the research plan. Glasses with lighting glass, with displays, for shielding purposes (the sun, sound and electric radiation) or to the receive are also possible. By the louver construction every louver can be covered with flexible functions and is interchangeable. This admits a multifunctionality and therefore a maximum flexibility.

The functionality needs an intelligent regulation technology and control engineering. The photovoltaic modul should be optimally directed according to the sun. The control of the other louver is depending on user's standards with regard to the temperature, the precipitation and the CO_2 concentration. The time course influences also the control processes. Three profiles of utilisation 1st school, 2nd office and 3rd industry should be compiled. In the user's profile school, the time breaks are favorable, e. g., to let some air in, at the same time control processes should run off very noiselessly.

The control coupled with the parameter temperature should occur about form memory alloys (FGL). This highly innovative basis of the "smart material" offers several advantages:

1. The function is integrated directly into the material.
2. With FGL the difference in temperature can be converted directly into mechanical work.
3. The system with FGL is able to act noiselessly.
4. Actor and sensor are united in a component.
5. The solutions with FGL can be constructed without technical detours.

The changeable facade module to be developed, should function completely self-sufficiently. Therefore, are the regulation processes and control processes which result from the parameters rainfall and CO_2 concentration to tune with the renewable energy entries from the photovoltaic louver and the amount of storage of the whole facade module.

All developments in the facade module are checked constantly in respect to sustainability and life cycle assessment. The changeability of the single elements, strictly uses of mono materials as well as the detachable connections in the whole facade module show the favorable condition of a sustainable construction. Regarding the life cycle an optimisation is carried out. For the life cycle analysis a parametric model is provided. A huge number of parametres can be evaluated by this approach in real-time basis.

New materials based on renewable materials, e. g., rice shells profile or bamboo or natural fibre-reinforced groups on the basis of partly based resinous systems as well as recyclated syntethetic materials can be used for the frame. For the advancement of the louver also clear plastics could be pulled up, for example, also biobased like cellulose acetate and new polycarbonate.

A material circulation is aimed. The facade gets on its new form as a "material leasing model" which is integrated into the material circulation.

3. State of the art

Glass facades correspond to the highest architectural demands and can be used in future more sustainable.

Planted louver modules are installed currently as stiff or movable louver in facades by buildings or halls, fig. 1. The particulate matter is bounded and the climate balance is improved. The facade receives a natural heat insulation, protection against cold and noise. With the self-sufficient facade module another landmark to the lasting facade should be reached.

Sustainable facade constructions are investigated internationally and are an object of numerous research activities. There are not self-sufficient active facade elements with the described functions. The potential of the building cover with regard to the necessity of a building taking into account the lifecycle was analysed in [4] and the need of constructive changes was concluded. In [5] and [6] introduced basis studies examine how the potentials of the bionics can be used to identify innovative attempts from the nature for new facade draughts.

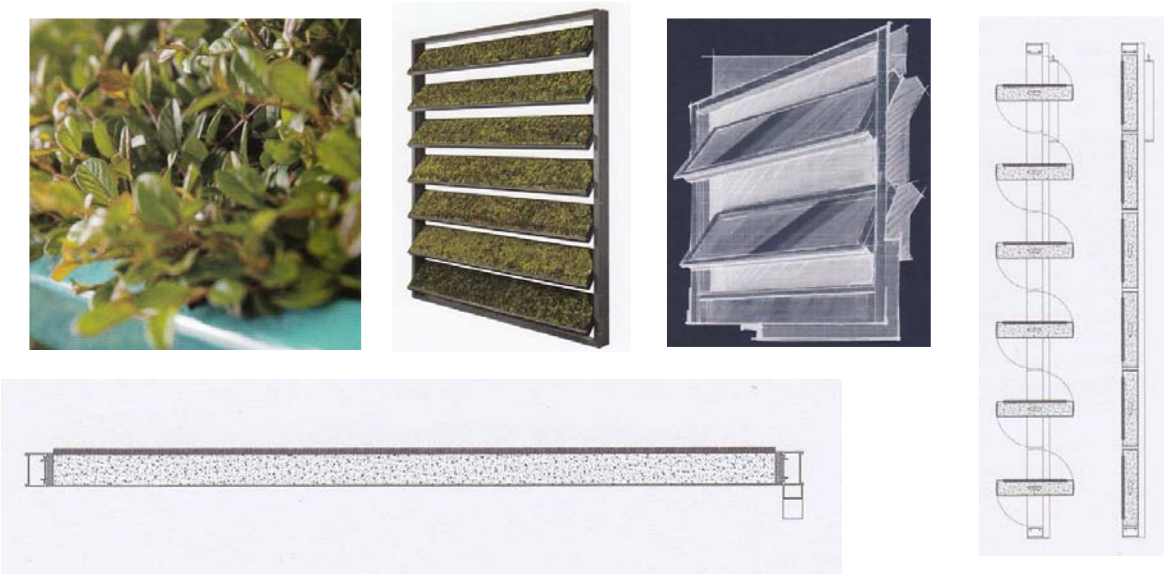

Fig. 1 Planted louver modules by EuroLam GmbH

Present research projects concentrate upon closed facades like in [7]. The facade superstructures are analysed taking into account the lifecycle, however, in a graduation for the planned research project not enough. The main focus of this work lies in the recommendation of a facade construction as a function of the geographical situation.

The aim of [8] is a multifunctional facade. This facade in [8] is not opaque and the multifunctionality is the transfer of the installations in the facade construction. In the research project is the innovative claim that the facade remains clear or transluzent, the universal duties like weather protection and airing are received and, in addition, other functions into the facades are integrated. To additional functions like the solar protection are moved by reflexion or absorption or with visible in colours or burglary protection with two or more windowpanes which are connected by one or several PVB foils to an inseparable unity.

The louvers in the area A are covered with photovoltaic. In [9] the best combination from PV-and solarthermie modules is analysed in connection with building technology components. The aims are high efficiencies for photovoltaic cells which are small and partially shadowed. From [9] knowledge flows in for photovoltaic louver on the subject high efficiency, low claims to the partwise shadowed, indirect light and long-lived. The entries of energy should be stored within the frame. The function of the warm storage, the integration of latent memories became (Phase-Change material, PCM) in [10] examines. Particularly in buildings with lower storage mass, typically with constructions of steel or of wood, these materials can serve to stabilise the space climate. In the production of the PCM the desired temperature of the phase crossing can be put.

The louvers in the area B can behave, e. g., thermo chrome, i. e. that they change the colour by temperature change. This process is reversible, i. e. on warming up or cooling the glasses accept their original colour again. Moreover, this process functions self-sufficiently, i. e. without additional energy which is transferred by electricity or is stored in electric fields. Big interest exists in the integration of safety glasses in the louver. In [11] constructive attempts are discussed to strongly reduce the weight of the safety glasses.

In [12] is the first facade leasing models from Stockholm published. Condition is a changeable construction. In [12] large-size facade elements are changed to be able to exchange uncomplicated facade elements accordingly of the available budget. In this research project this beginning is further deepened to receive a sustainable construction. Of the general resource shortage among other things from sand [13] [14] can be counteracted if the future buildings are understood as a raw material camp and are supplied by exchange or back construction to the material circulation again. The return of all construction materials in the material circulation is the key process of a sustainable constructions [15]. In [16] an innovative contribution of an entire residential building is built which is prefabricated completely in the factory, is constructible and back constructible and all materials / constructions are reversible connected. [16] based on a frame construction from profils. The integration of a storage in the frame which is room-sided interchangeable is not investigated up to now.

In the research the application is examined more alternatively of sustainable frame materials. Possible alternatives to the steel and aluminium profiles could be bamboo profiles or rice shell pressures [17] (approx. 60% of rice shells, 22% of stone salts and 18% of mineral oil). The application of lasting materials like the growing again resource wood is analysed in [18].

The control of the louver in the load case temperature should occur about form memory alloys (FGL). This highly innovative „smart material“ is documented for constructive uses in [19]. This alloy must be specified for every use. The systematic action to the specification is described in [20].

One possibility to grasp the environmental effect systematically is the method of Life Cycle Assessment LCA. The Life Cycle Assessment is explained in German Institute for Standardization EN ISO 14040 (2009) [21]. In the building sector LCA finds increasingly use. On the one hand building products are equipped with the environment-product declarations which are provided by the institute construction and environment [22]. On the other hand the data bank ökobau.dat shows data sheets of many materials with their ecological characteristics [23]. These are hardly applicable at the moment without processing the data for the LCA of buildings, because the base factor are varied and statements are not entire to the end of life of the material is unknown. Hence, online tools were developed in a research project promoted by the BBSR that the practical use allows [24]. This is still in the test phase and is used within the research projects and is developed.

The industrie produces high-quality louver windows. The presently in the market available louver windows of national and international manufacturers are used than:
- strong formative element in the facade
- for the fine adjustment of the airing for the smoke deduction and warm deduction
- to the better space in the room, use without preceding casements
- for the avoidance of accidents by open windows
- for the burglary protection

The louver has to be pursued in its main operational areas airing and fire prevention by electric energy supply, pneumatically or by manual work. The setting engines are fixted in the frame. The setting engine always brings a noise interference. There are not self-sufficient, themselves with energy supplying louver modules at the national and international market yet. A silent control is possible by the deformation depending on temperature of form memory alloys in the temperature load case. Intelligent functional materials „smart material“ like form memory alloys (FGL) are used if high forces and set ways on small construction space are needed. These demands are required by the integration of the control in the module frame. Examples of FGL from the auctoric are found in the areas biotronic, aerofit and mechatronic, like heave magnets, servo motors, bi metallics and deformations elements. They have sensory qualities and they are able to move factor 1.000 of their own weight. Compared with conventional steels FGL are deformable up to 100 times strong-stronger reversible. The use of FGL in or on a frame for his control is not published yet.

The frame construction of louver facades are made by several producers of aluminium. Renewable materials are not used as an alternative up to now. Ease, wear-resistance and weather permanence are essential demanded qualities to a frame profile in this use. The sustainability of a measure is valued by the life cycle analysis. Quick renewable materials can show an alternative to the available aluminium profiles in the louver profile, nevertheless, are not available yet.

In the frame integrated memories for electric energy there is not. Similar adaptations for the storage integration can be found, e. g., with electro longboards. The long-stretched accumulator would have to be adapted by the form and the achievement to the demands of the facade module. Here can be fallen back on analogies.

Panelles of photovoltaic exist in varied dimensions and are available. A simple adaptation to the louver size accordingly of the respective customer wishes is not possible up to now. The same component dimensions are required only in low numbers of pieces by which the production with the photovoltaic industry turns out difficult.
The energy entry of a louver of photovoltaic can be improved, while the louver corner is adapted to the sun. At the market panele of photovoltaic which line up after the time of day [25] are available. By the louver construction only one angel of movement (one rotation degree of freedom) is possible. Nevertheless, this should be optimally coupled to the angle of the sun.

To thermo chrome glasses react with a reversible color, based on a difference in temperature. The sensitive setting of the glasses on the temperature variation area of the user is still to be defined for this use and to construct.

The application of switchable electro chrome glasses allows an adaptation of the transmission spectrum and with it a control of the whole energy passage degree. This passes (with standard insulating glass superstructures of 12% with dark setting (light transmission = 15%) to 40% with bright setting (light transmission = 55%). The transmission portion, measured in a laminated glass disc about the whole solar spectrum (280 nm<λ<2500 nm), with glasses amounts to the radiation-physical characteristics dependent on wave in the decolorized state approx. 26% (light transmission = 66%) and in the colorized state approx. 3% (light transmission = 9%), [26].

Safety glasses are offered in different implementations. All offered glasses distinguish themselves by a high selfweight. This quality should be reduced in the research strongly. By this improvement sinks the required energy of the movable louver and the installation process is improved, from certain dimensions and the renovation case is more easy.

An essential main focus of the self-sufficient facade module to be developed is the changeability. The sustainability is strengthened by this. The changeability of a construction is perceived only during the change positively. The higher expenditure in construction affects mostly higher costs, therefore, the changeability is less used.
By the realisation of a change in a construction the changeability is perceived intensely. Nevertheless, by the integrative idea of the life cycle assessment the focus is set in the early planning phase. This thinking is not strong enough grounded in the industry and economy.

4. Innovations

The highly innovative, changeable, active facade module should be self-sufficient which consider aspects of the sustainability stronger and distinguish themselves with the newest assessment methods of the science and technology - the life cycle assessment - with especially high quality.

The autarky of the louver module should be able to air-condition the space air of the room and to provide the required energy for the control independently and to store energy. In the space the climate data temperature and CO_2 concentration are measured and sent to the facade module. In the frame outside temperature, precipitation and solar intensity are measured. The sensor works cablefree. The data are evaluated taking into account the time of day and information is escorted to the control of the photovoltaic of the louver and louver with additional function. The control of the load case temperature functions about FGL without electric energy supply and, in addition, noiselessly. The space climate control without acoustic interference shows an absolute novelty.

It is an essential contribution to the sustainable construction and therefore big advantage of the new development of this facade module that in the case of renovation only a very low intervention becomes necessary and a very low resource expenditure in the new building becomes necessary.

Sustainable facades must be changeably constructed, because only the change of the construction materials in the material circulation can counteract against future resource shortage. Changeability of the design features and in the best way possible the transportation of all construction details in monomaterials with an active self-sufficient facade module with adaptable functionality is a high development objective in the international graduation.

The up to now internationally unsolved tasks are
- Integration of the storage in the frame of the louver window
- Changebility / revision of the storage of the room side
- Energy entry about photovoltaic on at least one louver with very high efficiency under bad conditions
- Optimisation of active glass functions at the example of thermo chrome glass and light safety glass
- Control in the load case temperature with "smart material" - fine adjustment of the form memory alloys
- Construction of the detail of the control with FGL and material setting with application temperatures as well as effect dimensions
- Interactive self-sufficient control of the louver in dependence of the load cases temperature, precipitation, CO_2 concentration, solar irradiation, day sound season
- Use of renewable frame materials and solvable connections make clear the claim to the research job

In each solution of one task is an innovative product. In the union to the changeable active facade module originates a technical novelty which also unites the aspects of the sustainability and resource protection. The space climate control is solved with the development in completely new manner.

The control of the louver window should be realised about an App.

5. Methodoly

To develop a changeable active glass facade which can adjust the room air self-sufficiently, should be reached more than several part steps.

Changebility
The changebility it is reached, while with the construction only exchangeable connections are used. For this can be fallen back on the theoretical bases in [27]. The changeable construction and the nearly entire use of monomaterials permits the easy integration of technical innovations in the future.

Sustainable of the used materials and the whole module
The potential of regrowing materials as a CO_2 concentration storage attracts in the building sector now attention. Aim is to check the application possibilities of regrowing building materials and to extend them. To alternative construction materials like rice shell pressures, bamboo and other ones, searches are carried out with regard to their qualities, usability and sustainability. For this can be fallen back on the knowledge from the research project FOGEB [28].
The lastingness of the effect of the whole construction is valued about the ecological life cycle analysis (LCA). For this analysis are to be defined a huge number by boundary conditions and acceptancies. The scenarios must be developed for exchange, servicing and change of use which are derived from building use data. Besides acceptancies are to be investigated the time of life of the construction elements. Optimisation potentials can be used by the parametrische processing of the data of the different design variations.

Resource efficiency of the whole construction
The slight intervention in the building cover for the installation of the changeable active facade module and its self-sufficient working makes the measure to the space climate control resource-carefully. Other measures with the same effect to the comfort in the room demonstrate the the potential of the development.

Storage within the frame
For this task it is tried to transfer knowledge from analogous settings of tasks. A feasibility study is to be connected to the search with regard to the efficiency, of the dimensions, the weight, the sustainability, servicing and exchange cycles.

Multifunctionaly louver area A covered with photovoltaic
As a function of location, adjustment and shades of the facade different systems are analysed. As an assessment criterion is valid not only the yield and the level of utilisation of the elective system, but the complete ecological balance of the components. A parametrische modelling becomes carried out and afterwards the model with available ecological balance tools can be evaluated.
The area available on the louver should be used optimal. Innovations must be investigated and be adapted in arrangement with manufacturers.

Multifunctionaly area B of User's specificity
The louver below the area of photovoltaic can be submitted to different use. On the one hand even darkening glasses become to thermo chrome, analysed, on the other hand light safety glasses. Technical innovation from research projects close to subject are integrated, sustainable aspects are considered.

Control and regulation load case temperature with form memory alloy

For the optimal form memory alloy set ways, set forces, dimension tolerance, temperature areas must be known. Nevertheless, these parametres are depending on the dimensions and the use (colored or safety glasses) of the louver. It beguns with a set of parameters and will improve qualities of the glass louver in the development.

The theoretical basis of the innovative application of the FGL, the "smart material" in the construction area, was provided by [29]. On it building up construction and material variations are compiled for the planned use in the self-sufficient facade module. The demands and boundary conditions to the FGL will be defined and impregnated in the material.

The control of the load cases precipitation, CO_2 concentration, solar irradiation, time of day and season is carried out with the stored energy won in the facade module. For this a use by all dimensions of influence and priorities is programmed in the airing and solar adjustment. Sensor and transmitter are in the room. The program and another sensor and receiver are installed in the frame. The data processing and reaction of the louver take place on a real-time basis.

Autarky

The louver surface used for the photovoltaic, the climate terms in the location, the comfort area of the user and the efficiency of the storage are tuned so to each other that the facade module works self-sufficiently. Frictional energy, weights of the louver in the areas A and B, louver size, wind pressure and wind suction forces are other dimensions influencing the set process and must be analysed.

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Global Sequential Sensitivity Analysis for Building Energy Simulation of Residential Quarters

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Summary

In this paper a dynamic sensitivity analysis approach is presented, which uses the Elementary Effects method in connection with a moving mean smoothing function to get a ranking of the influence of parameters. This is demonstrated on a model of an urban quarter, which uses EnergyPlus to simulate 25 buildings of a block. The information for creating the building models stems from statistical, GIS and building typology data. For the majority of model parameters no data is available. Therefore assessing the influence of these parameters is crucial in order to give recommendations what data should be acquired in future projects to have the possibility to create reliable models for refurbishment scenarios of urban residential quarters.

Keywords: renewable energy supply, building energy simulation, sensitivity analysis

1. Introduction

Renewable decentralized energy supply of buildings will become more and more important and due to its fluctuation the focus of energy demand and supply calculations have to change from monthly or yearly cumulative examination to detailed hourly examination using transient simulation tools. Additionally existing buildings offer a huge range of possible refurbishment measures. Effects of these measures have to be considered in detailed examination to select the best option regarding all relevant target functions like peak power or self-sufficiency for electricity. Especially when looking at quarters consisting of multiple different buildings there is a huge range of possible measures which could be applied in the future.

Transient building energy calculations of residential quarters have many parameters (> 100 per building). Data about the building envelope (like geometry via GIS [7], constructions via building typology [5]), or annual energy demand [5] is available. But data about the used heating systems, local power generation or user behavior is insufficient. Therefore for modelling the buildings in detail, theat means with hourly results, considering interactions between building technology and renewable energy sources and their fluctuations, recommendations for data to be collected in the future have to be derived by analyzing the influence of different parameters on the model using sequential sensitivity analysis.

2. Methodology

An approach for extending the global sensitivity analysis method of Elementary Effects (EE) to assess dynamic effects of building's energy behaviour in a simulation model of a residential quarter is presented. In this approach sensitivity indices for every single hour of the year are calculated. The result is a time series with 8760 values. To evaluate this time series it is useful to use smoothing methods like moving means to reduce short-term fluctuations. The size of the moving mean window is important here and has to be adapted to the model result data. The basic idea for this method was developed in [14]. This method can be applied to other sensitivity analysis methods in a corresponding way, EE was chosen due to its relative low calculation effort.

2.1. Sequential Sensitivity Analysis

Dynamic sensitivity analysis is, compared to conventional sensitivity analysis, considering time within a simulation model and the change of parameters and results over time. So the outcome of the model is a time-series (like the hourly energy demand of a building), and therefore the sensitivity index is a vector with one entry for every point in time, for which the index was calculated. [14] As this vector can be seen as a sequence over time and to distinguish the method presented in the following from other dynamic sensitivity methods considering time, it is called sequential sensitivity analysis.

A sequential sensitivity analysis of a dynamic building performance simulation consists of the following steps:

- Select target functions and parameters of interest
- Use sampling strategy to create input sets for the parameters
- Run model with varying input parameter sets and save output as time-series data
- Use smoothing functions to reduce shortterm fluctuations
- For every input set and the corresponding smoothed output time series calculate the sensitivity index time series
- Plot the sensitivity indices over time

2.2. Elementary Effects

The Elementary Effects Method was developed in 1991 by Morris [1]. The aim of this type of sensitivity analysis is to identify parameters which are a) negligible, b) linear and additive, or c) non-linear or involved in interactions with other factors. For a detailed definition and possible interpretations of the results see [2].

2.2.1. Overview

EE is a sensitivity analysis method which uses as sampling strategy different trajectories of a discretized input space to vary every parameter. Every input can take p levels. The resulting sensitivity index μ shows the overall influence of a parameter on the output, while σ assesses the ensemble effect (nonlinear and/or due to interactions). Usage of μ^*, which is defined as the mean of the distribution of the absolute values of the elementary effects and therefore helps to minimize cancelling effects, is recommended. [2]

The computational cost of the calculation of the elementary effects sensitivity index is (k+1)*r runs of the model, where k is the number of parameters and r is the number of trajectories.

Recommendations to get valuable results are p=4 and r=10. [3][4]. The results in chapter 3 were calculated with p=4 and r=2, because r > 2 does not change the method itself, but reliability of the results and computational effort increases. Reliability of results is not in the focus of this paper, but minimizing computational time was necessary.

Parameters can also be grouped to reduce necessary runs, for mathematical details see [2]. This means, that all parameters in one group are changed at the same time in the same direction. The computational cost therefore reduces to (g+1)*r runs of the model, where g is the number of groups and r is the number of trajectories. Groups have to be created carefully, because if there are unsuspected interactions between the parameters in one group, this interaction is neglected in the resulting sensitivity index.In the example below grouping is used for the set point temperature at day and night (see 2.5.4).

2.2.2. Justification for using elementary effects

The EE method was mainly chosen because of its low computational effort and the simple possibility to use grouping, which is helpful in the context of the residential building quarter to model, where a lot of independent parameters exist.
In addition, due to the definition of μ_i , μ_i^* and σ_i , which are averaged over multiple local sensitivitiy measures to remove the dependence on the sample point, it is better than ordinary one-at-a-time sensitivitiy analysis methods regarding the exploration of the input space.
EE is quite robust regarding unstable models, i.e. if one model run for a chosen trajectory fails, this trajectory can be left out and another one can be chosen. This is especially helpful when analysing all parameters of a residential quarter which means a number of parameters in a magnitude of thousands, where not all combinations can be checked for stability before the sensitivity calculation. [2]

One downside of EE is that no quantitative analysis on the variance of the influence of a factor and the individual interactions between factors is possible. A variance based sensitivity analysis will be the next step when the number of factors can be reduced to the set of most important ones. Then also the individual interactions between factors can be assessed, what is not possible using EE. [4]

But for identifying the most important factors the EE method is a good compromise between calculation effort, interpretability and valuable results.

2.3. Moving Mean

Assume an odd window size w. Then the moving mean of the (w-1)/2 elements before and behind a fixed element x_i (i > (w-1)/2) are calculated by:

$$mm(x_i, w) = \frac{1}{w} \sum_{j=i-(w-1)/2}^{i+(w-1)/2} x_j \qquad (1)$$

2.4. Model of residential quarter

2.4.1. Description of the case study building block

The building block used as case study here consists of 25 buildings, which were constructed be-

tween 1918 and 1978. Therefore the building types DE.N.MFH.03.Gen to DE.N.MFH.06.Gen from the TABULA Building Typology [5] were taken as base information. The geometry of the buildings was taken from GIS LoD1 data available at [7].The overall heated area of the 25 buildings in the quarter is 10426 m² with 183 residential units. Heating in the block is provided by district heating (30% of heated area), gas (30% of heated area), oil (15% of heated area) and others (coal, solarthermal). Only district heating, gas and oil systems are modelled here, solar thermal heating will be implemented into the model in the future.
Climate data generated by Meteonorm for the city of Nuremberg was used for all simulations.

2.4.2. Energy simulation

The energy simulation is conducted using EnergyPlus models, which are parametrized using the data available in the building block. The models used here were created in [6] using information of the German part of the TABULA building typology [5].

2.4.3. Refurbishment activities

The method for representing refurbishment activities in the buildings was developed in [16] and uses normal distributions of the lifetimes of walls, windows and the roof construction to model points in time, when refurbishment measures can be conducted. Probabilities are used to decide, whether an energy improvement by insulation for the walls and the roof or better U-values for the windows takes place at such a refurbishment point in time. The probabilities change over the years to incorporate for increased energy refurbishment activities.

In this paper no projections into the future are considered. Therefore only refurbishments which were performed in the past are used to approximate the state of the building stock in the year 2015.

2.5. Model Parameters for sensitivity analysis

For this paper not all parameters can be assessed by the sensitivity analysis, so a subset was chosen, which represents the different type of parameters: factors of the building envelope, the heating system and user behaviour. The exact values for the distributions have to be analysed and justified in the future.

2.5.1. Conductivity of the insulation of wall constructions

A default conductivity of the insulation of 0.035 W/mK is assumed for all building age classes which have insulation applied. The thickness of the insulation is calculated inversely by using the given U value for the wall constructions. But for variations due to other materials used the conductivity parameter is changed by a normal distribution around the pregiven value of 0.035 W/mK as mean and standard deviation 0.05 W/mK.

2.5.2. Heat capacity of walls

The parameter $c_{p,Wall}$ is used to model the heat storage capacity of the external walls of the buildings. This information is not given in the building typology, so its importance will be investigated. The heat capacity of the static part of the wall changes, the insulation’s heat cacacity does not change. The heat cacacity is defined to vary by a normal distribution with mean 1000 J/kgK and standard deviation 100 J/kgK.

2.5.3. U-value of windows

From the building typology the U-value is given by values between 2.57 W/m²K and 4.3 W/m²K depending on the building age class. This value is varied for the sensitivity analysis by a normal distribution around that pregiven value from the building typology and a standard deviation of 0.1 W/m²K to represent different constructions.

2.5.4. Setpoint temperature at day and night

During day (defined to be the time between 6:00 and 21:00) the setpoint temperature varies between 19 and 22 °C. During night (21:00 to 6:00) it varies between 16 and 19 °C.
As these setpoint temperatures are used at different times of the simulation, the interaction between those two parameters is minimal when not looking at the load peak after the change from nightsetback to day operation. Therefore EE input factor grouping can be used here. If the day setpoint temperature is high, it is assumed that also the night setback temperature is high, and the same for low values. More temperature setpoint strategies and user behaviour related information will be implemented in the future and could use results like [13].

2.5.5. Fixed infiltration rate (constant over time)

This parameter defines how much air changes in the heated zone of the building due to infiltration. In the German standard [8], a value of 0.7/h is assumed. But older buildings tend to have much higher infiltration rates [9], so the influence of this parameter will be assessed for values between 0.2 and 2.0 1/h to address the wide variety of real buildings.

2.5.6. Increased airchange rate due to 1 hour window opening during the day

This parameter serves as one example for specific user behaviour. It models that every day for one hour between 7:00 and 19:00 windows the windows are open and therefore an increased air change rate (here an additional 2/h to the constant infiltration rate) has to be used. In reality a much wider bandwidth of window opening times, length of window opening and different air change rates can and will occur. But this parameter and its effect on the energy demand shows, that it is necessary to have more data available on the user behaviour in the future.

2.5.7. Heating System Boiler efficiency

For gas and oil boilers the efficiency is defined by a coefficient [11]. This coefficient varies for the sensitivity analysis by a uniform distribution between 0.5 and 1. This represents the over dimensioning of some systems, which will then not run in there optimal full load range but in a part load range which is less efficient. To model the partload curve will be a next step. For condensing boilers the efficiency coefficient could be greater than 1, but this is not supported in the Energy Plus model.

2.6. Validation

Neither detailled information about parameters of heating and ventilation systems nor measured data for energy consumption with high temporal resolution is area-wide or for the case study block available. So a physical validation of the model is not possible. But EnergyPlus with its components is validated [10], so the model described in 2.4 can be used to identify the most important parameters for the building block. Then recommendations what data should be collected in future projects can be created.

For privacy and cost reasons never all parameters and measurement data will be assessed. So it is crucial for validation of city quarter models to gain knowledge about the most important parameters to gather using sensitivity analysis methods of models.

3. Results

3.1 Final energy demand

In the following the simulation results and corresponding sensitivity indices of one winter week (January 9th till January 16th equal simulation hours 217 to 385) will be examined. This can be extended to a whole year analysis using the same methods described in 3.2, the moving mean window sizes have to be adapted.
For this paper the result we are most interested in is the final energy demand of the heating for all buildings, which is in average for all scenarios for the the whole week 196160 kWh.

Figure 1 shows the mean, mininmum and maximum of the specific final energy demand in all the different trajectories of the sensitivity analysis. The ratio between max and min curve is almost

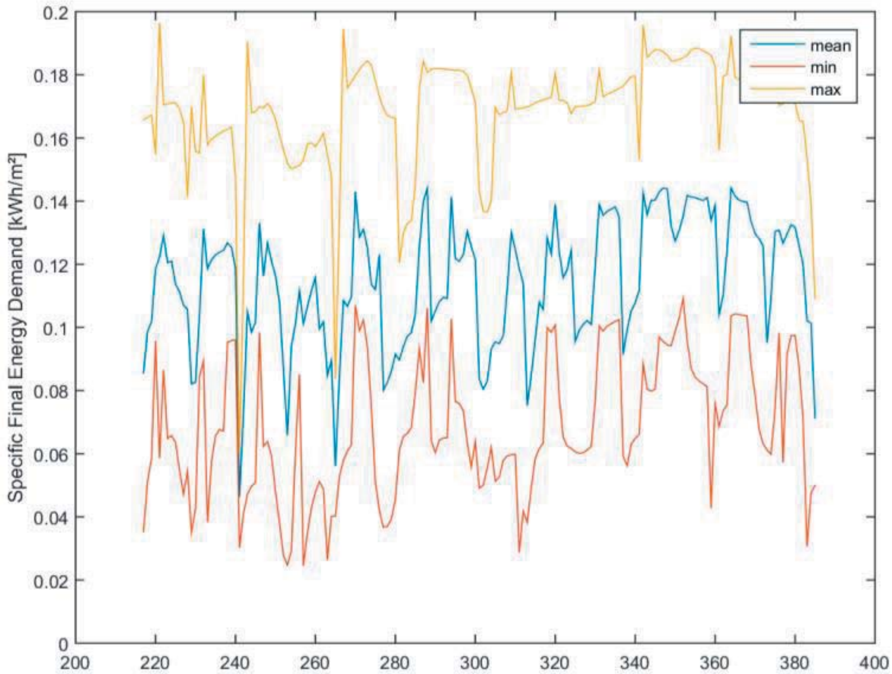

Figure 1: Mean, Min and Max of final energy demand

everywhere bigger than 2, so there is a quite high variation which will be explained by the sensitivity analysis in 3.2. Detailled examination of these results would extend the scope of this paper by far and is not necessary for demonstrating the sensitivity methods below.

3.2 Sequential Sensitivity Analysis

The sequential sensitivities of the model parameters explained in 2.5 are calculated and shown in 3.2.1. The effects of combining it with the moving mean method are explained in 3.2.2. Main reason for using a smoothing method like the moving mean is to have a better understanding of the overall importance of a factor over time intervals longer than an hour and to reduce short-term fluctuations. The error of the data underlying the sensitivity analysis increases. So a tradeoff between interpretability and reliability is necessary.

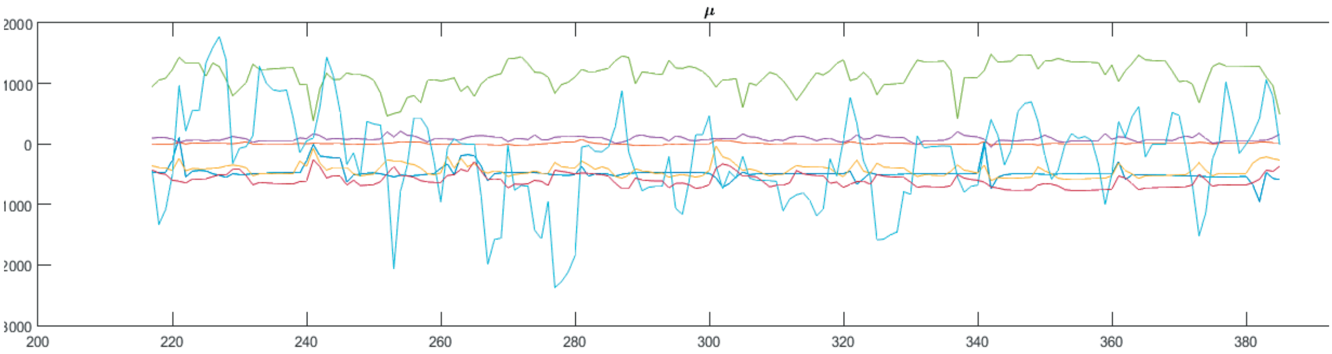

Figure 2: μ for the input parameter groups

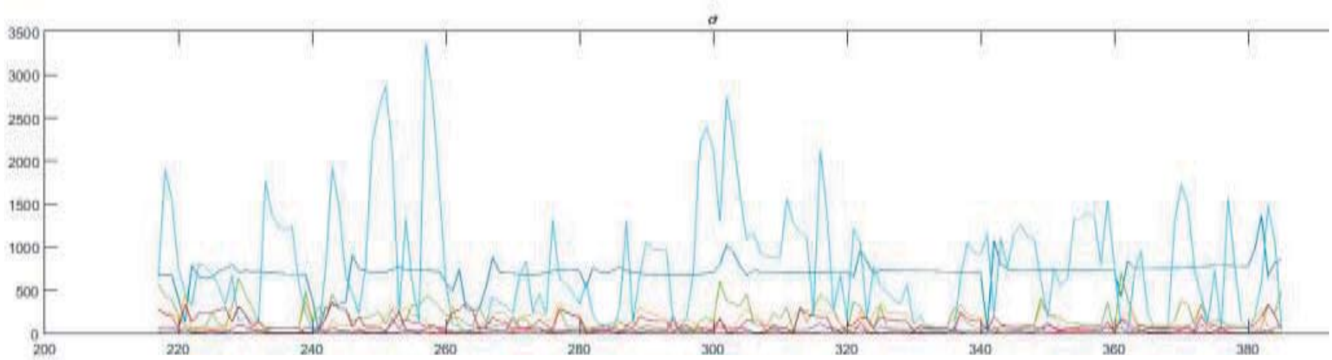

Figure 3: σ for the input parameter groups

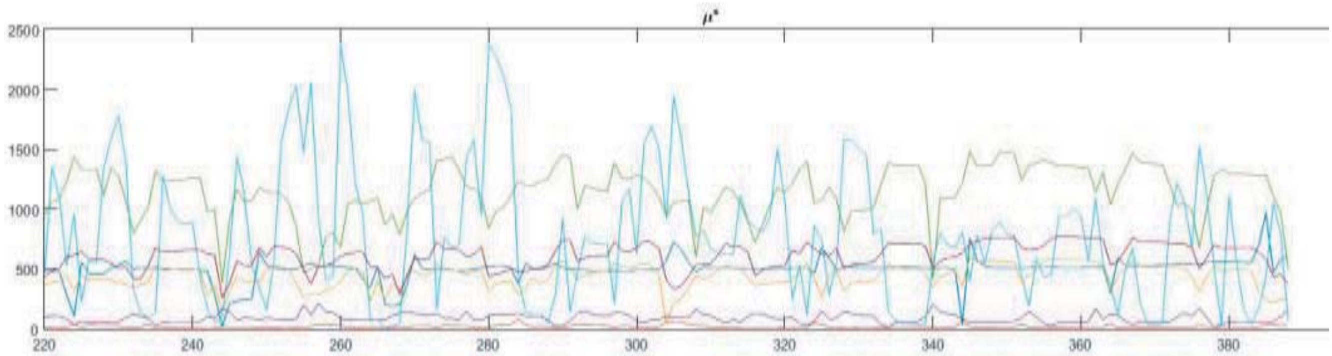

Figure 4: μ* for the input parameter groups

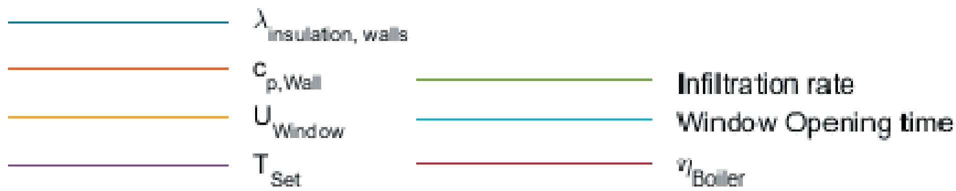

Figure 5: Legend for figures 2, 3, 4, 6, 7

3.2.1 Interpretation without moving mean

In figures 2, 3 and 4 the sensitivity indices μ_i , μ_i^* and σ_i are plotted for the input parameters described in 2.5.

It can be seen in figure 2 (and the same in figure 4 for μ_i^*), that in this time of the simulation the infiltration rate has the highest direct impact on the result, as μ_i for that parameter is almost everywhere maximal. The interaction of the infiltration rate represented by σ_i is only at some points in time noticeable.

μ_i for the window opening varies a lot, both in positive and negative direction, so here it is hard to compare its importance to the other factors. When looking at σ_i and μ_i^* of the window opening, at some points in time it is dominant over the other factors, so this parameter has strong interactions with other factors.

The conductivity of the insulation has a μ_i value comparable to the μ_i values of the U value of the windows and the efficiency factor of the boiler, but σ_i of the conductivity of the insulation is

almost all the time at about 700 kWh whereas σ_i of the U value of windows and and σ_i of the efficiency factor of the boiler is below 250 kWh.
In conclusion, beside the obvious strong impact of the infiltration rate, it is hard to see an explicit trend for a parameter importance ranking.

3.2.2 Interpretation with moving mean

In figure 6 already a clearer stratification of the values can be seen. This is helpful to identify the infiltration rate as most influential factor. For the efficiency of the boiler, the conductivity of the

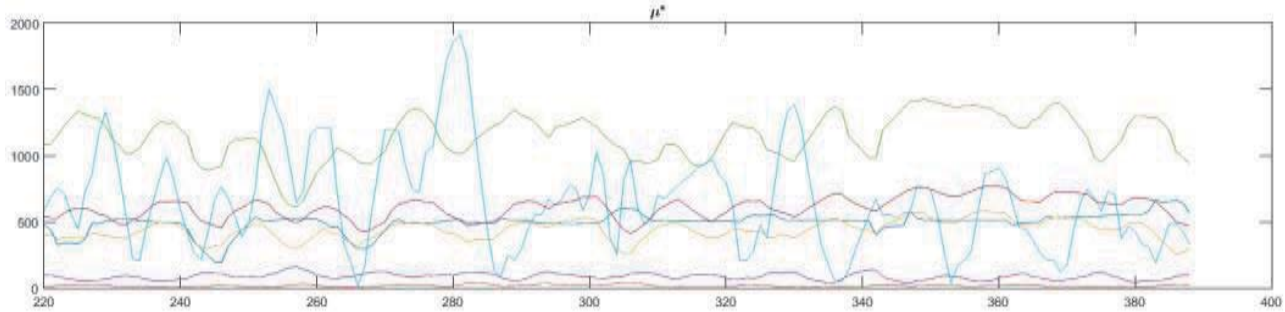

Figure 6: moving mean of μ* with window size of 5 hours (color legend in figure 5)

insulation and the U value the ranking is not yet clear, they are all in the same influence magnitude. The setpoint temperature has small influence, the heat capacitiy almost none. The influence of the window opening changes from almost none to maximum influence over this week, so here an importance ranking compared to the other factors is not possible.

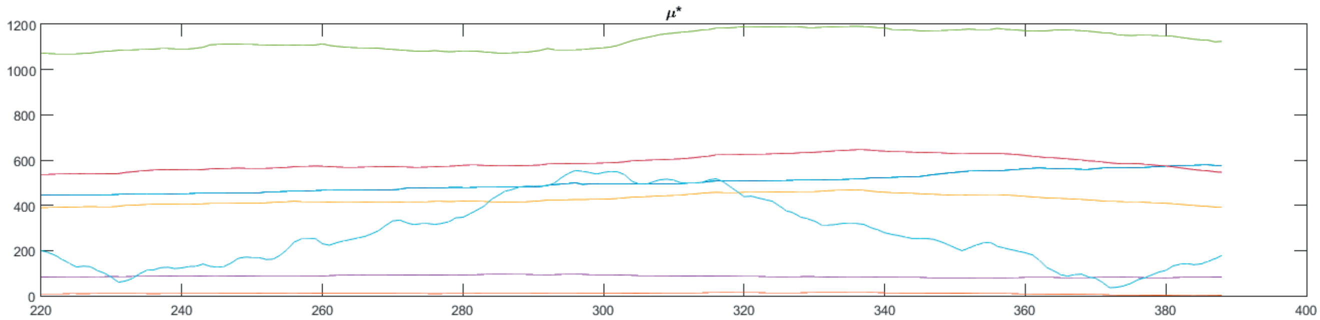

Figure 7: moving mean of μ* with window size of 95 hours (color legend in figure 5)

In figure 7 the stratification becomes obvious, so from that the influence ranking listed in table 1 can be created. Only the window opening parameter is still changing a lot over time, so for such kind of parameter the moving mean method is not helpful in creating an influence ranking.
Therefore usage of the moving mean method helps to get a parameter ranking when the sensitivity indices vary a lot in the hourly examination.

Table 1: influence ranking of parameters when using moving mean window size of 95

Parameter	Rank	Parameter	Rank
Infiltration rate	1	U value of windows	4
Boiler efficiency	2	Setpoint temperatures	5
Conductivity of insulation	3	Heat capacity of walls	6

When analyzing a whole year the moving mean window size of 95 hours is not suitable, the fluctuations are too big to get a parameter ranking. By extending the window size to 719 hours (appr. 30 days), the parameter ranking stratification becomes visible again for the time January to April and October to December. In the summer months the sensitivities mix up because of the low heating demand.

4. Discussion

4.1 Recommendations for data acquisition

The main result from the sensitivity analysis is that the infiltration rate is the most important factor regarding final energy demand in this model. So in the future, projects dealing with district refurbishments should collect information about the real infiltration occurring in buildings. For new buildings mandatory blower door tests generate that information, which is documented in the energy pass for a building. But there is no central registry collecting the data, so this information is not area-wide available. For the efficiency coefficient of boilers it would be helpful to also have a central registry collecting data for example through the sweep association. Regarding the conductivity of the insulation and the U value of the windows the base information given by the building typology can be used to get uncertainties of model results, but ranges about the domain of these parameters have to be defined using studies about real constructions. For the setpoint temperature studies exist showing how users behave in different situations [13]. For window opening, which have, as we see in the sensitivity calculations, sometimes a high influence on the results, the behaviour is not easy to explain [17]. For other shortterm fluctuating influences like electric device models exist, which could be coupled with the model presented here [18].

4.2 Outlook

This paper used just a small subset of parameters of the model for the sensitivity analysis. In the future more parameters will be added. Optimal would be an analysis of every uncertain factor, but this means thousands of parameters. Computational time is not a real problem nowadays and could be reduced by using parallel computing. But the effort for evaluating the results will increase, especially as more interacting parameters will occur, where the source for interaction has to be found. Additionally the timeframe, in which sensitivities are evaluated, has to be changed from a week to a year. The simulation model already calculates hourly values for the whole year, but the moving mean window size will have to be adapted to that. Other target functions for evaluating the sensitivities will be added, e.g. electricity purchased, electricity sold (due to local electricity generation), CO2 emissions, costs for fuel and refurbishments, and the ranking considering different target can then be compared.

Therefore additional methods for calculating and evaluating sensitivity indices have to be analysed. One possibility could be to use functional transformation (like Fourier analysis or principal component analysis) to transform the result functions to new coordinates better suited to the given model and then calculating sensitivity indices of these new coordinates. Another idea concerns the window opening parameter defined in 2.5.6, where the point in time of an event has to be considered. For such dynamic effects the method of impulse parametric sensitivity analysis [15] could be useful, which was established in the field of computational systems biology.

5. Conclusion

Using the moving mean method in connection with the Elementary Effects method gives a better understanding for the influence of parameters and its dynamics. Constant parameters like infiltration rate or U value of windows can be ranked easily. For parameters which define events like a one hour window opening at some time of the day the smoothing method is not very helpful, the dynamics of the overall influence and the interaction effects are still too variable. Here other methods have to be developed.

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Graphical User Interface for Plus Energy Multi-family houses

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Summary

The user habits concerning energy outline a key factor for the energy demand of a building - in addition to cubic content, quality of shell and efficiency of the technical systems. To integrate the user into the Energy Management can contribute to a lower energy consumption. The User Interface exploits those potential of saving energy: a tool via touch panel makes the tenants´ manner concerning energy transparent without infantilizing them. Moreover, the announcement of the availability of in-house gained energy encourages using this on-site renewable energy source. In fact, the focus rests on information, not automation. Since August 2015, the User interface finds his first application in practice in an eight floor building including 74 units which is built in Frankfurt: Aktiv-Stadthaus.

Keywords:

- Graphical User Interface
- user information
- personal´s and building´s energy production and demand
- plus energy multiple dwellings

1. Introduction

In energetic optimized houses r prospectively energy standards, the demand of electricity acquires an increasingly value across from the demand of heat. The consumption of the user comprises the largest part. Besides, the usage of energy efficient devices, one´s individual lifestyle influences this need significantly. The requirement of heat, domestic hot water and ventilation also vary applicable in dependence of the user. Accordingly, the user behavior presents a significant potential for saving energy in energy efficient buildings - next to cubature, quality of shell and efficiency of technical systems. Especially in plus energy houses the possibilities go beyond conventional measures for reducing the demand. The user is able to coordinate consciously his need with the temporal volatile offers on regenerative energy.

Consequently, measures have been identified how to support the user reflecting his own manners concerning energy and at best matching them appropriately. The announcement of the availability of regenerative gained, self-sufficient power belongs to that.

The User Interface bases on the previous completed research project “Aktiv-Stadthaus”. It finds a first precise application in the inner-city Aktiv-Stadthaus in Frankfurt which is built by ABG Frankfurt Holding.

The eight storey multiple dwelling in efficiency house plus standard supplies 74 units with electricity produced by the photovoltaic systems on the roof and on the facade. The heat is gained by the waste water of the nearby Gutleut canal with the help of a heating pump. In the ground floor there are offers of car sharing via book-n-drive. Three out of the eight cars are e-cars. The tenant clientele is supposed to be mixed towards upper mid-sized classes. The first prototype of the User Interface is proved and tested in this house since August 2015. A socio-scientific monitoring goes along with the user and values the acceptance and the effectiveness of the created tool.

The graphical User Interface has been developed by the following research questions:

- Which information does the user need in order to be motivated to an energy saving behavior?
- In which scale of detail should the information be transmitted?
- Which information could evoke a contra-productive or alienate effect?

The project´s aim is to gain new knowledge about the interaction between user´s behavior and energy efficiency of multiple dwellings.

With regard to an economical handling of energy, the user´s personal need is made transparent in a playful way. The announcement of in-house gained electricity presents another potential in order to optimize the household´s energy demand.

Therefore, the inhabitants get an energy management tool which is easy to use. A graphical User Interface via touch panel should motivate the user to save energy respectively to use the in-house gained renewable energy without being patronized.

2. Methodology

An interdisciplinary team, consisting of experts in architecture, energy and building technology, programming, graphics, socio-science and housing industry works on the graphical User Interface. The conception and the design have been developed basing on the previous research project “Aktiv-Stadthaus”. Finally the team realizes a first prototype for the first implementation in the pilot project in Frankfurt. In principle, the User Interface is adaptable to further multi dwellings and independent from vendors and systems in order to guarantee a general application.

The following work packages present the essential steps in order to reach the overall objective.

[1] Conception
[2] Programming
[3] Evaluation
[4] Revision and finishing
[5] Cut surface monitoring

[1] Conception

During the past project some functions have already been formulated. The content was verified with regard to technical and software based feasibility and the design was revised concerning usability and functionality. Right from the start, the idea focused on system openness and upon the general transferability to further buildings. Socio-scientific and technical aspects influenced the layout significantly. It was analyzed which kind and which depth of information the user require in order to be encouraged to an energy saving behavior. The effectively impacts and the user acceptance will be explored and valued in business.

[2] Programming

The system design necessitates a high extent of flexibility, because it´s supposed to achieve the requirements of the pilot building Aktiv-Stadthaus and is ought to be adaptable to similar projects in the future. With regard to maintainability and reusability, the system is composed in a modular way. The web server is the core piece. It is hosted in a computer center and provides the data base. The collected information is visualized in a web browser. Thereby, the User Interface is not fixated on certain devices, formats or fabricants. The web browser can be simply embedded in a native App for smart phones or tablets. A gateway establishes the cut surface between the data of real energy, user and system in the building and the central server. It collects information of the building service, converts them into the User Interface´s format and sends them cryptographically secured to the central web server.

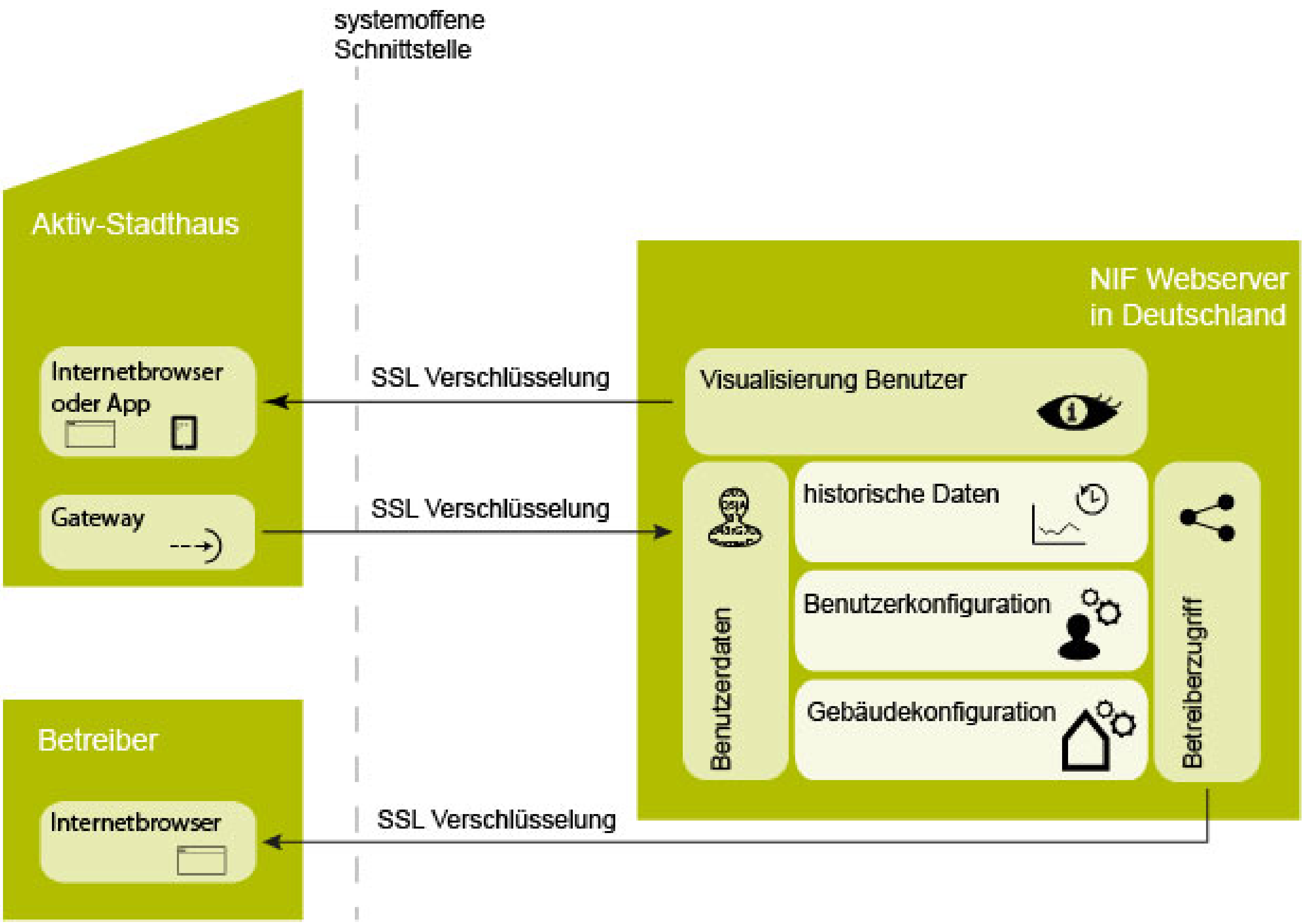


Fig. 1: system structure, source: TU Darmstadt, unit ee, modified according to mondayVision

The software package is set up by three components:

A administration interface – backend

This part serves the management of the single elements (flats, user, energy budgets and so on).

B website – frontend

The required information could be recalled on an interactive and for the iPad Air optimized website.

C app for Apple iPads

The frontend, respectively the website, which mainly consists of the browser window, is shown to the tenant in the form of an app.

[3] Evaluation

Basing on the first prototype, the user-friendliness was evaluated by a socio-scientific study with focus groups which represented the tenant clientele. The results were mainly positive. The test user favored the design and could imagine integrating such a tool into the daily life. The annotations significantly influenced the revision concerning usability, clarity and comprehensibility.

[4] Revision and finishing

In conclusion, the content, design and programming have been optimized. Within the official opening of the pilot building in Frankfurt the first prototype went into operation.

[5] Cut surface monitoring

After the completion the efficacy of the User Interface will be valued via a socio-scientific monitoring which will be performed within the scope of the user survey of the project «Effizienzhaus Plus Standard». Referring to this, additionally issues and questions concerning the User Interface, its acceptance and its importance for the tenant´s behavior are formulated.

3. Results

In the course of the run time, the interdisciplinary team developed a first prototype which was ready to go into operation in the Aktiv-Stadthaus since August 2015. The structure and mainly contents are represented in the following.

3.1 Structure

User mode. Three different user modes allow various levels of detail regarding content and function. The “Mietermodus” (tenant mode) forms the basis of all 74 units. Each renter receives information on the production of in-house gained, renewable energy as well as data and analyses of the individual energy demand for heating, domestic hot water and electricity. A deeper degree of information is available in ten of those dwellings. The so called “Expertenmodus” (expert mode) additionally shows the ambient temperature of one main room and the energy consumption of several devices. Beyond that, the user of the “Aktivmodus” (active mode) could also program the start of the mentioned gadgets via the touch panel.

Energy budget. A needs-orientated energy budget for thermal and electrical energy is calculated for each dwelling in order to maintain the efficiency house plus standard. By the means of such a credit it is expected that the user is encouraged to an energy saving behavior. In the case of the pilot building Aktiv-Stadthaus the responsible housing enterprise bears the costs for greater consumptions of warmth until 2020. The consumptions of electricity which exceed the budget will be charged.

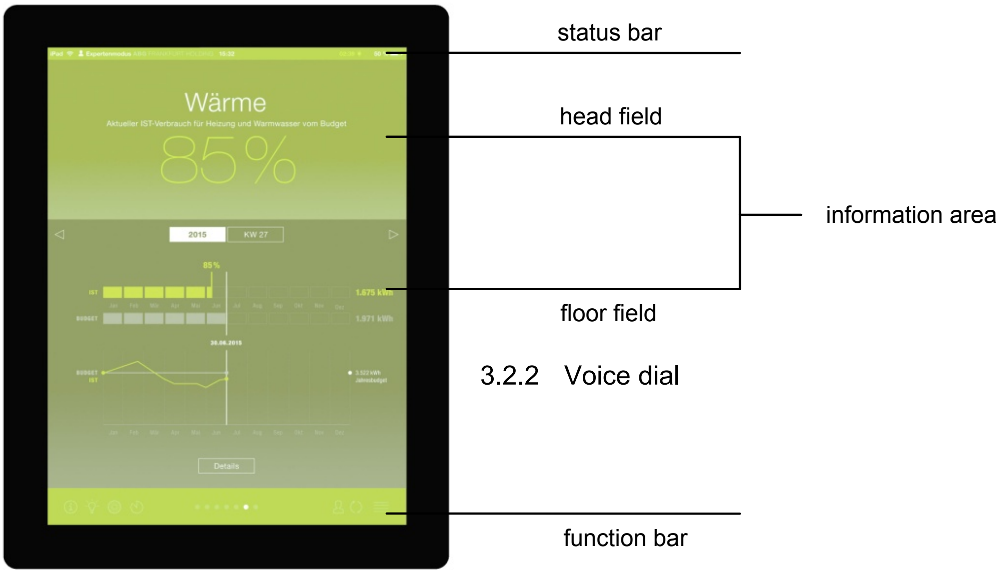
Energy production and demand. The tenant is informed about the building´s consumption as well as about the production of the in-house gained energy out of the photovoltaic system. A straight comparison between both components could evoke irritation because of potentially negative balance values. In order to prevent unsureness, the User Interface illustrates the solar coverage rate on the building´s consumption. The software also provides a 48 hour-announcement of internally gained solar electricity. The renter could at best fit his or her behavior to this. Further, the project surpasses the conventional report of the current consumption per kWh and supplementary provides a comparison per kWh and % to the calculated budgets. One can either receive information on the past 7 days (week-view) or choose the year-view where data of the last months are presented. By these means, the tenant is given the opportunity to evaluate his energy performance independently and possibly optimize his or her consumption. Additional tools to cope with the issue “energy efficiency” in a playful way are the options “Feedback” and “Ranking” which offer an analysis or anonymous comparison to other tenants.

Add-ons. In order to enhance the acceptance and a frequent application, the tenants receive services such as a manual or tips on saving energy. Another beneficial option is the possibility to hire cars or e-cars via the provider book-n-drive of which one rental station is located in the ground floor of the pilot building Aktiv-Stadthaus. The tenants of the active mode can additionally program the start of some tools remotely - either manually or semiautomatic via the so called “smartmode”. This mode gives the signal to launch the machine as soon as there is a surplus of solar-based, self-sufficient power during a selected time frame.

3.2 Design

3.2.1 Construction of the display

The general structure is inspired by the model of the Apple weather app. The display is built up from three sections. The largest in the center presents the information area which is divided into two further parts (head field and floor field). The main information is situated in the head field and visualized in detail via graphics and diagrams in the floor field. The always present status and function bars are located above and below. The status bar shows general information so as the user mode. The symbols in the function bar lead to further information and functions.



3.2.2 Voice dial

Fig. 2: construction of the display, source: TU Darmstadt, unit ee

Energy efficiency poses a complex topic and is mainly communicated via a technical way of speaking. Particularly with regard to user-friendliness, the User Interface overcomes this obstacle by the means of a generally comprehensible language. The term “Wärme” (warmth) is a suitable example which led to various discussions in the team meetings and also in the frame of the evaluations. Finally, the item remains “Wärme”, is explained in a guide book and is split up into “Heizung” (heating) and “Warmwasser” (domestic hot water) which is also mentioned right in the main menu. A further point is a non-patronizing voice dial to motivate to an energy saving behavior. At the start of the project, the menu option “Sonnenstrom verfügbar” (solar power available) was named either “Strom verbrauchen” (consume electricity) or “Strom sparen” (save power). On the one hand a request could seem like a dictation, on the other hand like an invitation to waste energy in the case of “Strom verbrauchen”. The next idea has been to announce the availability or non-availability of solar gained, self-sufficient energy. The risk concerning the second issue is that one could be confused about the security of supply as well as one doesn´t have the more important information when regenerative-based energy is disposable again. After all, the subtitle below the menu point “Sonnenstrom verfügbar” poses a hint to the time specification whether it´s the period of disposability or the duration until the next expected availability. Altogether, the team reached the aim of a quick and easy understandable language - particularly the options of the main menu could be reduced into single strong terms.

3.2.3 Color and graphics

Additionally to language, the design is also developed regarding a positive, motivating and on top of that clear appearance.

Color. One basic decision was to soften the tough red into orange. In general, colors are applied purposeful which means using orange as rarely as possible and highlighting positive feedbacks or energy efficient aspects via an affirmatively yellowish-green.

Graphics. The complex information should be easy to enter and easy to understand. Regarding this, for instance, the details about the individual consumption are contrasted with the calculated budgets in two different ways. One graphic, following the apparition of an amplifier, presents the current state of usage. A diagram below shows the course of the past days/months via a cumulated graph of the own usage referencing the budget.

Fig. 3: screen chronology for warmth, source: TU Darmstadt, unit ee

Another example poses the option “Feedback” where you can acquire an analysis of your energy performance in view of the last 7 days. If one mainly stays on his budget concerning power, heating or domestic hot water during this term, it is rewarded by a star in the corresponding category. This representation turned out to be more motivating than positive/negative signs.

Fig. 3: feedback, source: TU Darmstadt, unit ee

4. Discussion

The present research project intended to support optimizing the energy demand of household´s in Plus Energy multi-family homes by making energy production and demand transparent. Regarding this, an interdisciplinary team developed a tool which informs tenants in Plus Energy multi-family dwellings about in-house gained energy production as well as about the building´s and the individual consumption of energy. The focus on information surpasses already existing energy management tools which concentrate on building automation.

Basic questions were which data should be made accessible for the user in order to induce an energy saving behavior and which information might evoke contra-productive effects. One preexisting challenge in the specific pilot building was the ownership structure which expanded the issue towards some conditions. Some scheduled options couldn´t be realized due to technical building installations. Further options, for instance a communication service for messages to the tenants are graphical prepared for prospective projects.

Apart from this, during the process became clear that an essential issue it is not only what, but better how to communicate facts. An already mentioned suitable example is the option “Sonnenstrom verfügbar”. Another instance is the option “Aktiv-Stadthaus” where one can read out the solar coverage of the building´s energy consumption. At the project´s beginning, the production was directly contrasted with the usage so that also negative values might occur which in turn could evoke anxiety about the security of supply. Concerning the informational content itself, a first evaluation with test data revealed a positive feedback about the facts on the individual performance. However, options like “Ranking” where you can anonymous compare your behavior to this over the other tenants appeared less interesting. These results could be presumably attributed to the point that the test user don´t really live or will live in this house. The scale of detail turned out to be well selected and visualized.

At the beginning, some contents weren´t scheduled such as the energy concept, the manual or the glossary. It was noted that some uncertain expressions are inevitable, even if they are not subject-specific. Presenting the energy concept also benefits the accessibility to the issue “energy efficiency”.

At the project´s run-time, it arose the question which amount of additional general options is subserve. On the one hand they favor the acceptance and enhance the frequency of use in the daily routine. On the other hand there is also the risk that the tool is more used for the extra services than for the basic purpose. Moreover, some offerings such as Email or Calendar are already used via certain single Apps. Another way to reach more consideration of the tool in the day-to-day life could be a reward system for remaining within the budget, being in the Top10 in the ranking, reducing the consumption et cetera. Possible gratifications might be vouchers for services from cooperation partners, for example book-n-drive in the case of the Aktiv-Stadthaus.

Another idea emerged in connection with the announcement of the availability of solar-based power and the thoughts about rewards which couldn´t be implemented in the current project. A time frame within there is surplus regenerative gained power could provide a kind of “HappyHour” in which energy is either at a lower price or even for free. This concept is suggested to enhance the motivation to conform the individual need to the availability.

5. Conclusion

It is a challenging business to transfer the anyhow complex topics into a generally comprehensible manner. The interdisciplinary structure of the team was in fact necessary in order to meet the requirements and capabilities of building technology, graphic, programming and socio-science. It also turned out that the ownership status is associated both with limitations and benefits. Some contents and functions either depend on this and on financial and technical basic requirements. Programmability is another challenge and entry point in terms of ideas. Overall, the vast amount of complex information could be reduced to a well selected level which is visualized in a modest and classy appearance. Each screen provides the most essential information and leads to further pages if needed. On the one hand this solution avoids overcharged displays which make it difficult to point out the necessary data. On the other hand the technical monitoring benefits from this structure which enables to identify the most commonly used options. Moreover, it turned out that designing based on models is auxiliary in view of readability and user-friendliness. Symbols like an “i” standing for the manual are quicker accessible than an also in the project tried paper clip meaning attachment.

Beyond this, the mainly positive results of the first evaluation show that people can imagine integrating such a tool into their everyday life and using it regarding saving energy. The outputs confirm the focus on information and not on managing like already existing tools. Concerning the targeted identification with the building the social scientific study features a demand for optimization. In fact, the test user have not been in the real renting situation. That is why a statement following the social monitoring, which will be made after one year past the opening in 2015, might be more valid. Otherwise, there are already upgradable ideas like the “HappyHour”.

In the case of the pilot project Aktiv-Stadthaus the touch panels are installed in every unit. This clearly limits the significance of the success monitoring referring to a lower energy consumption. For a stronger contrast, one might consider a prospective project which arranges that the User Interfaces are applied in half of a multiple dwelling. Such a strategy even provides the further important opportunity to point out the cost and benefit ratio of such systems. Since the actual User Interface is still a sponsored research project, estimated prizes couldn´t be commented.

6. Acknowledgements

Truly, creating such a tool requires a balanced interaction between various subject-specific components. In effect, the developing of concepts for prospective similar projects should at best start early on together with the design phase in order to guarantee at least the technical basic conditions.

Retrospectively, in the course of the project´s short run time of about one year, there rest open questions like with the point of the tenant´s identification with the building. As already mentioned, the following social scientific and technical monitorings will provide valid results regarding the frequency of use and the acceptance. Due to the statements and mainly favorable outputs of the first evaluation with test user, it can be suggested that people are both interested and poised to integrate such a tool into the everyday life. That is why an expanding demand for such innovative projects can definitely be expected.

At the end the success strongly depends on the user´s individual lifestyle which in fact cannot be generalized. There will always be a demand on further projects which focus on the cut surface between people and technology. The tool described here provides a solid base and extendable ideas for such prospective researches. If we carry on involving the user, we are able to identify more weaknesses and could in fact achieve an increasing success. The purpose is: not only saving energy through automation - rather through information.

Green Buildings: A Concept aligning the interests of Stakeholders (Developers / Clients and End-users) in Estate Development Projects in Abuja - F.C.T (Federal Capital Territory), Nigeria.

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Summary

Nigeria is the most populous country in Africa, with Abuja as its capital city. The Population of growth rate of Abuja is about 25% - 45% annually and is expected to 10million by 2018. This explosive growth rate has created severe housing problems resulting in overcrowding, shortage of electricity and water supply, other degrading public infrastructure, and deplorable urban environment etc. Many Housing estates were developed by both Public and the Private sectors but do not reflect the desired housing needs of the end-users. Incorporating green building features are basically at the developer's disposal but should be checked with potential end-users because it affects rental and sales value. The objective of this paper is to identify green building features that can be incorporated in housing estate development projects which can align the interests of the Stakeholders specifically the Developers/Clients and the End-users / Occupants. Review of literatures helps identify and narrow few environmentally sustainable elements in the particular context of Abuja. A *5-point Likert scale* questionnaire survey was conducted on Estate Developing Firms and Occupants / End-users from 20 different housing estates in Abuja; selected through random sampling method. The results showed that green building features such as; *Energy Efficiency, Water efficiency, Building Envelope, Indoor Environmental Quality and Day-lighting systems* were the favoured and affordable green building elements that can unify and align the interests of both the Residential Estate developers (clients) and the End-users (Occupants) in estate development projects in Abuja.

1. Introduction

Nigeria is the most populous African country located in western Africa; a former British colony till October, 1960 when it gained independence. Lagos (a coastal city) was then the capital city till December, 1991 before the seat of power was moved to Abuja within the Federal Capital Territory (FCT) in the same year. Geographically, the FCT is located at the centre of Nigeria. Abuja under Köppen climate classification features a tropical wet and dry climate with three weather conditions namely; warm, humid rainy season and a blistering dry season; with a brief interlude of harmattan in between the two (WECSI 2014, demographia.com; and Wikipedia.org)

Abuja is considered among the fastest growing cities in the world, with a population of about 330,000 in 1990; 1.995million in 2010; presently about 4million; projected to reach 10million by 2018-20 (Muhammad 2013; Sundaram, 2012; demographia.com; Wikipedia.org). This shows that the Population growth is about 25% - 45% annually and affirms the rate of migration of people in

Nigeria to its capital city Abuja in the FCT. This explosive growth rate has created severe housing problems due to high demand resulting in overcrowding, inadequate electricity (power) and water supply, other degrading public infrastructure, deplorable urban environment especially the Built environment etc. Despite being a pre-planned city, Abuja is also affected by spontaneous and uncontrolled urbanization like any other city in a developing country and has led to growth of suburban city-like districts and springing up of many satellite towns around the city.

1.1 Housing challenges in Abuja and Nigeria at large

Social housing schemes in the form of state and federal low cost housing schemes has been the housing policy of the Nigerian government in the 1960s to early 1980s, but it was abandoned due to series of military coups and their regimes. This led to shortages of Housing in most of Nigeria's urban areas and has remained a mirage to all carder of the society in Nigeria (Olotubara 2007 as cited by Toyobo et al., 2011).

Housing demand in urban centres (like Abuja FCT) is a manifestation and reflection of different household desires to live in an urban centre (Todd, 2007, Akinyode & Tareef, 2013), which is increasing at an alarming rate. Various reasons have been attributed to an increasing taste for urban living which includes employment opportunities, urban amenities and utilities consumption opportunities (Olayiwola et al, 2005). This situation has consequently led to housing shortages where most people are found living in non-decent building apartment due to their socio-economic background which cannot cope with ever increasing price of decent houses (Ibid).

Abuja FCT, like any other capital city of a developing country is not exempted from the housing problems; as it continues to grow in population and expand in physical terms, the housing conditions have continued to evoke considerable concern due to its effects on the built environment and also, the need for modern infrastructure that wiIl serve the needs of the present and the future. This goes a long way in affirming the increase in global population growth accompanied by massive resource consumption and its negative impacts on the environment.

The built environment showcased the impact of human activity on resources; buildings have a significant impact on the environment, accounting for one-sixth of the world's freshwater withdrawals, one-quarter of its wood harvest, and two-fifths of its material (Eurostat, 2011); 40% primary energy consumption (Bauer et al., 2007). Structures also impact areas beyond their immediate location, affecting the watersheds, air quality, and transportation patterns of communities (Eurostat, 2011). The combination of these challenges gave birth to a new concept in design, construction / renovation, operation and maintenance of buildings in conformity with sustainable practices known as Green Buildings (Dalibi, 2014).

Successful delivery of projects, their operations and management (including green building projects) is attributed to many factors of which stakeholders' perceptions, participation, roles and responsibility are among (Bourne, 2005 and Dalibi, 2014). Stakeholders' input, participation, roles and responsibility in Green buildings projects must be of high cognizance than conventional building projects because of the divergent stakeholders' interests. These warrants the need for embracing green elements in estate development projects in Abuja based on the stakeholders requirements and interests.

1.2 Research Problem

The problems of housing supply in meeting the ever increasing housing demand remains one of the most pressing problems facing Nigerian urban centres (Israel and Basiru, 2008). Although residential quality studies have gained increasing attention in recent times, the majority of such studies was foreign and focused mainly on factors affecting the quality and performance of construction, particularly in public or social housing programs within specific housing environment (Shinnick,1997; Djebarni and Al-Abed,1998, Saari and Tanskanen,2011). A few studies conducted locally have focused on the perception of residential quality in selected neighbour hoods (Ebong, 1983; Ibem, 2012); whereas others addressed the socio-cultural dimensions and patterns of housing quality (Akinola, 1998; Jiboye et al., 2005; Olayiwola etal., 2006; Jiboye 2010). The absence of building measures regarding green building features in the Nigeria's national building codes of 2006 further showcased the newness of the green building concept in the Nigeria's construction industry.

Over the years, many housing estates were developed by both the Public and the Private sectors or a partnership of both in the Abuja FCT in the form of Quantitative housing that can be rented out or sold out. However, Such Housing estate developments were insufficient in terms of demands; do not reflect the desired housing needs of the end-users; in most cases affordable but not qualitative; do not possess green building features. This is compounded by inadequate electricity (power) and water supply for residential consumption in Abuja and many other urban centres in the country.

Fenn et al., 1997; pointed out that incompatibility of interests amongst stakeholders caused conflicts and disputes in construction. Notwithstanding, Berke (2002) advocated the holistic inclusion of different interests from stakeholders and involving the public in planning. Incorporating the various interests of stakeholders should be extremely important for the preparation of green specifications, construction and maintenance.

Though, green building construction practice is a new trend (about two-three decades old) in construction with insufficient data about the costs. There has been an absence of measured building performance data from currently operating sustainably designed buildings (BD&C 2003; ENSAR 2003; Andreau et al., 2004). It is evident from some developers'/ clients' attitudes, as they are not fully inclined towards constructing such projects due to lack of comprehensive data about the financial obligations with regards to Incorporating green features into renovation or proposed projects, Premiums, Marketability, Ratings, Cost of renting, Operating and Recurrent costs, Cost – benefit from envisage energy and water savings etc.

Matthiessen and Morris, 2004; opine that the first question often asked about sustainable design is: what does "green" cost, typically meaning does it cost more? This raises the question: More than what? More than comparable buildings, more than the available funds, or more than the building would have cost without the sustainable design features? The answers to these questions have been thus far elusive, because of the lack of hard data. These ultimately impact the decision abilities' of various stakeholders especially developers.

Morris, 2007; argued that "The most common reasons cited in studies for not incorporating green elements into building designs is the increase in first cost"; the cost of incorporating sustainable designs elements depends on a wide range of factors which includes Building type, Location, Climate, Site conditions and the Project team. These factors may have relatively small or big but noticeable impact on green building developments in Abuja and cumulatively, they make a difference.

Sustainable design elements are gradually accepted in the mainstream of project design, and building owners and tenants are beginning to demand and value those features. It is important to note, however, that advanced or innovative sustainable features can add significantly to the cost of a project and that these must be valued independently to ensure that they are cost and or environmentally effective (ibid).

Incorporating green building features / elements are basically at the developer's disposal in Nigeria's estate development projects and these may have a significant impact on the total development cost which in turn affects end-users / occupants in terms of Rental value, Sales value, Envisaged savings due to green elements, Future asset value of the green building etc.

Thus, those elements if not checked with potential end-users in order to ensure they meet their housing needs, requirements and also their affordability which will also reflect on the developers' interests in terms of market value and faster sale of the Housing units. These all together outlined the need for housing estate development projects with features that can align the interests of the stakeholders in such development projects.

1.3 Research Aim

The aim of this paper is to identify green building features / elements that can be incorporated in housing estate development projects which can align the interests of the Stakeholders specifically the Developers/ Clients and the End-users / Occupants; in the context of the hot-humid climate in Abuja. Review of literatures in the Eco/green/sustainable building field helps identify and narrow few environmentally sustainable passive and active elements that will be applicable in the particular context of Abuja.

1.4 Research Hypotheses

The following hypotheses were formulated for this research; T-test statistical tool was used in testing these formulated hypotheses:

Null hypothesis (H_O); there is no significant difference between the preferences and interests of Residential Estate developers (clients) and the End-users (Occupants) when choosing Green building features/ elements in estate development projects in Abuja.

Alternative hypothesis (H_A); there is a significant difference between the preferences and interests of Residential Estate developers (clients) and the End-users (Occupants) when choosing Green building features/ elements in estate development projects in Abuja.

2.0 Review of Literature

2.1 Green buildings

Green Building refers to a structure that uses all processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from Siting to Design, Construction, Operation, Maintenance, Renovation and Demolition. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort (*USEPA*, 2009).

Greg Kats, 2003; defined sustainable or green buildings as those sensitive to the environment, resource and energy consumption, impact on people, financial impact and the world at large. While Zane *et al,* 2009; referred to the term “Green Building” as environmentally friendly practices from building design to the landscaping choices. It also encompasses energy use, water use, storm-water and wastewater re-use. According to Dalibi, 2012; Green buildings are buildings designed, constructed and operated using Sustainable Materials and resources that provide optimum performance of the building with positive impact to the occupants and the environment by combining energy, water efficiency systems, Day Lighting strategies, Indoor Environmental Quality (IEQ) systems and efficient Building Envelope systems.

The United States environmental protection agency as cited by Vatalisa et al., 2013; opine that “Although new technologies are constantly being developed to complement current practices in creating more sustainable buildings, the common objective is that green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment through the goals of sustainable building such as Life cycle assessment (LCA), Energy Efficiency and Renewable Energy, Water Efficiency, Environmentally Preferable Building Materials and locally have focused on the perception of residential quality in selected neighbour hoods (Ebong, 1983; Ibem, 2012); whereas others addressed the socio-cultural dimensions and patterns of housing quality (Akinola, 1998; Jiboye et al., 2005; Olayiwola etal., 2006; Jiboye 2010). The absence of building measures regarding green building features in the Nigeria's national building codes of 2006 further showcased the newness of the green building concept in the Nigeria's construction industry.

Over the years, many housing estates were developed by both the Public and the Private sectors or a partnership of both in the Abuja FCT in the form of Quantitative housing that can be rented out or sold out. However, Such Housing estate developments were insufficient in terms of demands; do not reflect the desired housing needs of the end-users; in most cases affordable but not qualitative; do not possess green building features. This is compounded by inadequate electricity (power) and water supply for residential consumption in Abuja and many other urban centres in the country.

Fenn et al., 1997; pointed out that incompatibility of interests amongst stakeholders caused conflicts and disputes in construction. Notwithstanding, Berke (2002) advocated the holistic inclusion of different interests from stakeholders and involving the public in planning. Incorporating the various interests of stakeholders should be extremely important for the preparation of green specifications, construction and maintenance.

Though, green building construction practice is a new trend (about two-three decades old) in construction with insufficient data about the costs. There has been an absence of measured building performance data from currently operating sustainably designed buildings (BD&C 2003; ENSAR 2003; Andreau et al., 2004). It is evident from some developers'/ clients' attitudes, as they are not fully inclined towards constructing such projects due to lack of comprehensive data about the financial obligations with regards to Incorporating green features into renovation or proposed projects, Premiums, Marketability, Ratings, Cost of renting, Operating and Recurrent costs, Cost – benefit from envisage energy and water savings etc.

Matthiessen and Morris, 2004; opine that the first question often asked about sustainable design is: what does "green" cost, typically meaning does it cost more? This raises the question: More than what? More than comparable buildings, more than the available funds, or more than the building would have cost without the sustainable design features? The answers to these questions have been thus far elusive, because of the lack of hard data. These ultimately impact the decision abilities' of various stakeholders especially developers.

Morris, 2007; argued that "The most common reasons cited in studies for not incorporating green elements into building designs is the increase in first cost"; the cost of incorporating sustainable designs elements depends on a wide range of factors which includes Building type, Location, Climate, Site conditions and the Project team. These factors may have relatively small or big but noticeable impact on green building developments in Abuja and cumulatively, they make a difference.

Sustainable design elements are gradually accepted in the mainstream of project design, and building owners and tenants are beginning to demand and value those features. It is important to note, however, that advanced or innovative sustainable features can add significantly to the cost of a project and that these must be valued independently to ensure that they are cost and or environmentally effective (ibid).

Incorporating green building features / elements are basically at the developer's disposal in Nigeria's estate development projects and these may have a significant impact on the total development cost which in turn affects end-users / occupants in terms of Rental value, Sales value, Envisaged savings due to green elements, Future asset value of the green building etc.

Thus, those elements if not checked with potential end-users in order to ensure they meet their housing needs, requirements and also their affordability which will also reflect on the developers' interests in terms of market value and faster sale of the Housing units. These all together outlined the need for housing estate development projects with features that can align the interests of the stakeholders in such development projects.

1.3 Research Aim

The aim of this paper is to identify green building features / elements that can be incorporated in housing estate development projects which can align the interests of the Stakeholders specifically the Developers/ Clients and the End-users / Occupants; in the context of the hot-humid climate in Abuja. Review of literatures in the Eco/green/sustainable building field helps identify and narrow few environmentally sustainable passive and active elements that will be applicable in the particular context of Abuja.

1.4 Research Hypotheses

The following hypotheses were formulated for this research; T-test statistical tool was used in testing these formulated hypotheses:

Null hypothesis (H_O); there is no significant difference between the preferences and interests of Residential Estate developers (clients) and the End-users (Occupants) when choosing Green building features/ elements in estate development projects in Abuja.

Alternative hypothesis (H_A); there is a significant difference between the preferences and interests of Residential Estate developers (clients) and the End-users (Occupants) when choosing Green building features/ elements in estate development projects in Abuja.

2.0 Review of Literature

2.1 Green buildings

Green Building refers to a structure that uses all processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from Siting to Design, Construction, Operation, Maintenance, Renovation and Demolition. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort (*USEPA*, 2009).

Greg Kats, 2003; defined sustainable or green buildings as those sensitive to the environment, resource and energy consumption, impact on people, financial impact and the world at large. While Zane *et al,* 2009; referred to the term "Green Building" as environmentally friendly practices from building design to the landscaping choices. It also encompasses energy use, water use, storm-water and wastewater re-use. According to Dalibi, 2012; Green buildings are buildings designed, constructed and operated using Sustainable Materials and resources that provide optimum performance of the building with positive impact to the occupants and the environment by combining energy, water efficiency systems, Day Lighting strategies, Indoor Environmental Quality (IEQ) systems and efficient Building Envelope systems.

The United States environmental protection agency as cited by Vatalisa et al., 2013; opine that "Although new technologies are constantly being developed to complement current practices in creating more sustainable buildings, the common objective is that green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment through the goals of sustainable building such as Life cycle assessment (LCA), Energy Efficiency and Renewable Energy, Water Efficiency, Environmentally Preferable Building Materials and

Specifications, Waste Reduction, Toxics Reduction, Indoor Air Quality, Smart Growth and Sustainable Development, Environmentally Innovative materials and services

Another definition by green building solutions is that: green building design and construction provide an opportunity to use resources more efficiently, while creating healthier and more energy-efficient homes and commercial buildings. "Green building is a holistic concept that starts with the understanding that the built environment can have profound effects, both positive and negative, on the natural environment, as well as the people who inhabit buildings every day. Green building is an effort to amplify the positive and mitigate the negative of these effects throughout the entire life cycle of a building (USGBC 2007)

Thus, the Green building elements and features considered in this work (based on *US EPA 2009; Gregg Kats 2003; Zane et al, 2009, Dalibi, 2012;* Vatalisa et al., 2013; greenbuildingsolutions.com; USGBC 2007) are limited to the following:

1. Energy Efficiency systems,
2. Water Efficiency systems,
3. Day Lighting systems,
4. Indoor Environmental Quality (IEQ) systems,
5. The Building Envelope systems.

2.2. The significance of Stakeholder engagement in green buildings

Stakeholder engagement is increasingly being recognised as more than just a defensive response to criticism or imminent conflicts. In some companies it has transcended into an integrated part of systematic risk management. Furthermore, effective stakeholder engagement is increasingly contributing to organisational resilience and flexibility, to learning and innovation, to the identification of new opportunities, and ultimately to the improvement of sustainable performance (Partridge et al., 2005).

To date, however, green building measures have not been widely adopted, with the exception of energy efficient systems (Gottfried, 1996). Too few green building demonstration projects today provide the industry with needed "how-to" information that reduces the perceived risk of "pioneering." Moreover, building owners and tenants are often aware of the connection between building-related environmental improvements and increased building economics and value, as well as increased occupant productivity (Ibid).

As such, incorporating the various interests of stakeholders is extremely important in green building projects from the preparation of green design, specifications, to green construction, operation and maintenance. This is done by acquiring all relevant information on green buildings, interpreting this information and effectively disseminating the information to persons who might need or involved in, and influenced by such projects. Communication is so important to project success that it has been referred to as the lifeblood of a project by many practitioners (Awati K., 2010).

The 5th edition of the project Management body of knowledge (PMBOK) published by the project management institute (PMI); outline Project Communications management and project stakeholder management as part the ten core knowledge areas. These two knowledge areas intersect first at the planning phase with one process each, namely; Plan Communications Management and Plan Stakeholder Management. This affirms the need for effective communications among the stake holders to enable success of projects especially green buildings.

3. Methodology

Secondary sources of data such as journals, conference/seminar/workshop papers, text books, newspapers, magazines and the internet etc. were used to review literatures in the green building field which helps identify and narrow few environmentally sustainable passive and active elements that will be applicable in the particular context of Abuja, Nigeria. A *5-point Likert scale* questionnaire survey (as the primary source of data) was conducted on both the developers and the end users.

Twenty eight estate developing firms and seven five hundred Occupants / End-users from twenty different housing estates in Abuja were administered the questionnaires randomly. Frequency count tables, Mean item score and T-test statistics were used for data analyses. The interest of the stake holders in any green building feature is aligned if the value of the mean item scores is in the range of either “agreed or strongly agreed”

4 Data Presentation, Analyses and Results

The Primary data for this research work was obtained through manually distributed questionnaires from twenty eight estate developing firms and seven hundred Occupants / End-users from twenty different housing estates in Abuja, Nigeria.

Table 1: Questionnaire Responses

Questionnaires	**Developers**		**End-users**	
	Frequency	*Percentage*	*Frequency*	*Percentage*
Returned	20	71%	508	73%
Non-Returned	8	29%	184	26%
In-complete	0	0%	8	1%
TOTAL	28		700	

The table above clearly shows that the overall response from the target populations is good with 71% of developers responsive and 73% of the end-users also responsive.

4.1 Results from the Administered Questionnaires

The table below shows the responses from twenty Residential estate developers in Abuja obtained from manually distributed questionnaires regarding green building features that can be incorporated in their developments which will align their interests with the End-users’.

Table 2: Responses of Residential Estate Developers in Abuja

	GREEN BUILDING FEATURES	**Strongly Agreed =5**	**Agreed =4**	**Undecided / Neutral = 3**	**Disagreed =2**	**Strongly Disagreed =1**	**TOTAL**	**Mean Item Score**
1	**Energy Efficiency**							
	Solar panels	20					20	**5.00**
	Wind turbines					20	20	**1.00**
	DC Inverters	7	8	5			20	**4.10**
	Solar-water-heaters	4	6	8	2		20	**3.60**
2	**Water Efficiency**							
	Grey & Black water systems		2	7	7	4	20	**2.35**
	Water saving appliances	16	4				20	**4.80**
	Rainwater harvest	10	5	5			20	**4.25**
3	**Day light**							
	Clerestories (eg. Top,Side etc)	9	10	1			20	**4.40**
	Spectral Glazing (e.g Photochromic, thermo	1	5	5	9		20	**2.90**

	chromic glass etc)							
	Solar-tubes	15	4	1			20	**4.70**
4	**Indoor Environmental Quality**							
	Indoor Air Quality	14	6				20	**4.70**
	Acoustics	17	3				20	**4.85**
	Adequate Lighting (Artificial+Natural)	10	10				20	**4.50**
5	**Building Envelope**		7	6	7		20	**3.00**

Source: Author's field survey 2015

The table below shows the responses from Five hundred End-users from twenty Residential estates development projects in Abuja regarding green building features that can be incorporated in residential estate developments to align their interests and the Developers.

Table 2: Responses of End-users of Residential estates in Abuja

	GREEN BUILDING FEATURES	Strongly Agreed =5	Agreed =4	Undecided / Neutral=3	Disagreed =2	Strongly Disagreed =1	TOTAL	Mean Item Score
1	**Energy Efficiency**							
	Solar panels	397	103				500	**4.79**
	Wind turbines		179	200	106	15	500	**3.09**
	DC Inverters	412	88				500	**4.82**
	Solar-water-heaters	298	155	44	3		500	**4.50**
2	**Water Efficiency**							
	Grey & Black water systems	23	105	131	189	52	500	**2.72**
	Water saving appliances	489	11				500	**4.98**
	Rainwater harvest	431	64	5			500	**4.85**
3	**Day light**							**0.00**
	Clerestories	96	392	9	3		500	**4.16**
	Spectral Glazing	89	108	144	90	69	500	**3.12**
	Solar-tubes	213	188	55	44		500	**4.14**
4	**Indoor Environmental Quality**							
	Indoor Air Quality	299	201				500	**4.60**
	Acoustics	371	125	4			500	**4.73**
	Adequate Lighting (Artificial+Natural)	244	199	33	24		500	**4.33**
5	**Building Envelope**	27	311	108	54		500	**3.62**

Source: Author's field survey 2015

The result of the various mean item scores (from table 1 and 2 above) for each green building feature were compared to ascertain the features that align the interest of both stakeholders as shown in table 3 below.

Table 3: Green Building Features that align the interest of the stakeholders

	GREEN BUILDING FEATURES	Mean Item Score for Developers	Mean Item Score for End-users	COMMENTS
1	**Energy Efficiency**			
	Solar panels	5.00	4.79	**Interest aligned**
	Wind turbines	1.00	3.09	**Interest not aligned**

	DC Inverters	4.10	4.82	**Interest aligned**
	Solar-water-heaters	3.60	4.50	**Interest aligned**
2	**Water Efficiency**			
	Grey & Black water systems	2.35	2.72	**Interest not aligned**
	Water saving appliances	4.80	4.98	**Interest aligned**
	Rainwater harvest	4.25	4.85	**Interest aligned**
3	**Day light**			
	Clerestories	4.40	4.16	**Interest aligned**
	Spectral Glazing	2.90	3.12	**Interest not aligned**
	Solar-tubes	4.70	4.14	**Interest aligned**
4	**Indoor Environmental Quality**			
	Indoor Air Quality	4.70	4.60	**Interest aligned**
	Acoustics	4.85	4.73	**Interest aligned**
	Adequate Lighting (Artificial+Natural)	4.50	4.33	**Interest aligned**
5	**Building Envelope**	3.00	3.62	**Interest may be aligned**

Source: Author's field survey 2015

4.2 Testing of Hypotheses

The hypotheses formulated for this research work was tested using T-test statistics. The values for the mean item scores in table 3 above were used as the data for the statistical computations as shown in the table below.

Table 4: T- test statistical results

STAKE HOLDERS	MEAN	STANDARD DEVIATION	N	DF	STANDARD ERROR	Tcal	$Ttab_{0.05, 26}$
1. DEVELOPERS	3.8679	1.1658	14	26	0.3702	**-0.8286**	**2.0555**
2. END-USERS	4.1746	0.7479	14				

Source: Author, 2015

With 26 degree of freedom (DF) and 5% level of significance the T-test tabulated ($Ttab_{0.05, 26}$ = 2..0555) is greater than T-test calculated (Tcal= -0.8286); as such, the Null hypothesis is accepted; which states that "there is no significant difference between the preferences and interests of Residential Estate developers (clients) and the End-users (Occupants) when choosing Green building features/ elements in estate development projects in Abuja".

5. Conclusions

From the limited green building features used in this study (Shown in table 1,2, 3 and 4) , it can be observed that both the Clients/Estate developers and the End-users agreed, disagreed and remain neutral on certain green building features in terms of their interests in estate development projects in Abuja. This affirms that both shared almost the same interest regarding the features of green buildings; which is further attested by the T- statistical test by accepting the null hypothesis. The following features as shown in table 3 above can align the interests of both the stake holders:

1. Solar panels**,** DC Inverters and Solar-water-heaters under Energy Efficiency systems.
2. Water saving appliances and Rainwater harvest under Water Efficiency systems
3. Clerestories and the use of solar tubes under Day-lighting strategies.
4. Indoor air quality, Acoustics and Adequate Lighting (Artificial lighting + Natural Lighting) under Indoor Environmental Quality.

Green Roof Integrated Photovoltaics: Technologies and Application on an Urban Development Project in Hamburg, Germany

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Summary

Since some years, there exist technologies, which enable the combination of solar technologies with a vegetated roof. Several studies have been conducted to learn more about the significant synergy effects of green roof integrated photovoltaics (GRIPV). The following ones are the main benefits: increased output of the photovoltaic system, ballast provided by the green roof build-up obviate the need for delicate roof penetrations, sunny and shady habitats increase the green roof`s plant diversity. Due to the persuasive study results as well as various possibilities for subsidies, gradually more projects have been put into practice. With that in mind, a study for green roof integrated photovoltaics on a forty-year-old high-rise complex in Hamburg has been elaborated, taking into consideration the complexity and challenges of its context. The results show that the most important benefits of such a system would be: 1) partial reduction of water stress on the area caused by storm-water run-off, 2) reduction of discharge in the existing sewerage system, 3) on-site renewable power generation that could cover the demand of about 26% of the households, 4) recovering the costs of both the green roof and PV-system in a reconcilable amount of time.

Keywords: photovoltaic systems // green roofs // Green Roof Integrated Photovoltaics (GRIPV) // decentralised stormwater management // synergy effects due to PV/plant interaction

1. Introduction

Over the years, rooftops have taken up an increasingly important role in sustainable urban development. Various roofing technologies are available, and a number of objectives can be pursued - be it vegetated green roofs as a supplement for existing stormwater management infrastructure, rooftop mounted photovoltaic panels to generate on-site electricity or white roofs to alleviate the urban heat island effect [1]. Until some time ago, especially the first two practices have been in competition with each other. This “either/or” question was based on the fact, that green roofs were, among others, promoted to capture and temporarily retain storm water, while an installation of PV panels usually involved a penetration of the sensitive roof covering - unquestioningly two contrasting objectives.

Since a few years, there exist roof configurations, which enable the combination of these two sustainable techniques. With these combined systems, the PV panels are installed on a base, which is held safely in place by the green roofs system build-up superimposed load [2]. However, not only the optimal use of the - limited - rooftop space is convincing but also the positive interactions between both [3]. Several studies have been conducted to find out more about the manifold synergies - by example, Hui and Chan [4] examined the increase of PV output due to the plant and PV interaction, while Lamnatou & Chemisana have done a selection of appropriate plant species for PV-green roofs [5]. Due to the persuasive study results as well as various possibilities for grants, gradually more projects have been put into practice. As a consequence, photovoltaic panels on green roofs are becoming increasingly common in the urban fabric.

2. Methodology

This paper aims to give an overview on the integration of green roof and photovoltaic systems as well as to incorporate the technology in an existing urban settlement. Hence, the paper is organized as it follows: 1) the system of green roof integrated photovoltaics is explained pointing out the functionality principle and the synergy effects, 2) information about the framework and the context for a possible implementation in a high-rise building in Hamburg are given, 3) the results of the dimensioning, calculations and dimensioning of green roof integrated photovoltaics are described and compared with a black as well as retention roof, 4) innovation potentials, beneficial effects and limitations of such a project are discussed, and 5), a conclusion is made.

3. Green roof integrated photovoltaics (GRIPV)

Green roofs as well a rooftop-mounted PV systems are both well equipped with persuasive benefits. Green roofs’s objectives involve the interception, retention and - later on - evaporation of precipitation water as well as the decrease of the stormwater runoff’s volume, reducing the surface water flows and the stress on public stormwater sewers [6]. Thus, green roofs treat the water as close to the source as possible - namely in situ on the building’s roof - and are therefore an effective strategy for water sensitive urban design [7]. Some additional green roof benefits involve thermal insulation and fire protection, the moderation of urban heat island effect, improved microclimate as well as increased biodiversity and air quality [8].

PV systems do not only become increasingly popular because of their manifold, but they are also perceived as a promising technology in the persistent struggle to reduce carbon dioxide emissions. Since the first conventionally produced PV cell in the late 1950s, the technology employed in PV systems has undergone further development in recent decades. Nowadays, the industry’s production of PV modules for residential use is steadily increasing, and a variety of profoundly tested systems are available.

Since more than a decade, there are systems available, which combine green roofs and photovoltaic systems. Since their launch, solar green roofs are increasingly seen in the built environment. This is due to the efficient utilisation of the rooftop area as well as due to the significant synergy effects of green roof integrated photovoltaics [3].

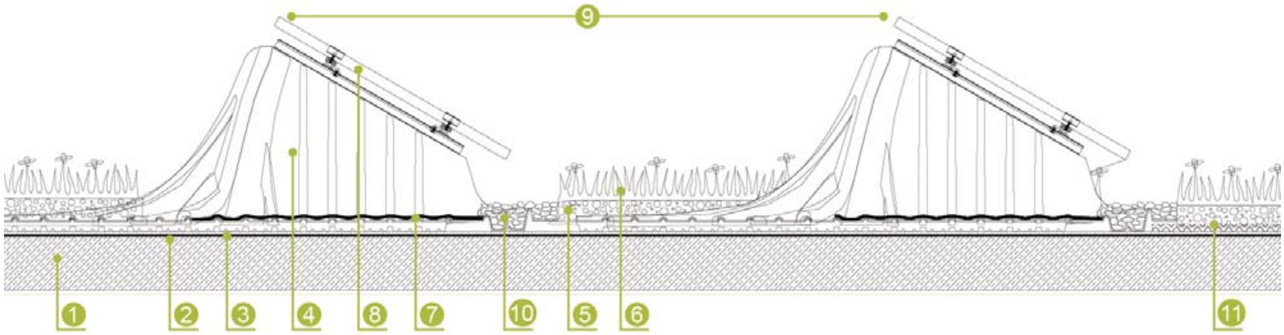

Fig. 1: A possible system build-up of GRIPV // Source: based on [9] // own graphic.

3.1 Functionality principle of green roof integrated photovoltaics

The system build-up of GRIPVs is similar to the one of an extensive green roof and is composed of various layers (Fig. 1). A suitable roof construction (1) is covered with a root resistance waterproofing membrane (2). The waterproofing membrane, as well as the roof construction, is protected from mechanical damage with a storage fleece (3), which additionally retains water and nutrients. The solar base modules (4) are placed on the fleece (3) and then covered with substrate (5) and vegetation (6). Rainwater is conducted underneath the modules by a capillary fleece (7). It not only provides water to the plants under the modules but also cooling through evaporation. On top of the solar base modules - which can be made of aluminium profiles or recycled HDPE - the PV panels are mounted (8). Various tilt angles are available and usually range between 25° and 45°. In order to avoid mutual overshadowing and with that a decrease in generated energy, the module rows should be positioned with sufficient distance (9). The height of these solar base modules is creating sufficient distance between the substrate layers and the PV panels, supplying the plants with enough rainwater and sunlight as well as enabling appropriate maintenance. In between the module rows, it is recommended to lay out a gravel strip (10). It simplifies maintenance work on the PV panels and simultaneously prevents the vegetation from being trampled. Furthermore, the vegetation-free strip prevents shadowing from higher plant species. Remaining roof surface area, which is not suitable for PV panels, can be laid out with a standard extensive green roof build-up (11).

3.2 Synergy effects of green roofs and PV systems

Several studies have revealed, that multiple synergy effects arise when green roofs and PV systems are combined. The benefits are not unilaterally - the green roof and the solar panels positively influence each other. Among the beneficial influences of green roofs on the PV systems it possible to cite the following ones:

1) Different investigations and experiments have been carried out to prove the increased PV efficiency due to the beneficial cooling effect, which is caused by the evapotranspiration at the plant level [10]. Lamnatou and Chemisana have summarised the percentages of PV output increase in the article titled “A critical analysis of factors affecting photovoltaic-green roof performance”. Depending on the location and the type of experiments, the values of PV output could increase as high as 8.3% [5].
2) According to Lamnatou et al., particular plant species are favourable, because they reflect incident irradiation and with this the amount of radiation over the PV module is enhanced.

Thus, a high percentage of plant coverage with light-coloured leaves increases the roof reflectivity and therewith the PV output [5].

3) The plants are not only beneficial during warm periods. Due to their thermal capacity, the plants protect the PV panels from the cold [11].
4) The electrical efficiency of solar panels is affected by accumulated dirt and dust on the PV module surface. Due to the fact, that green roofs can help to reduce dust levels and herewith improve air quality, the performance of the PV panels could be enhanced [4].

The beneficial influences of photovoltaic on green roofs are summarised as it follows:

1) Due to the PV panels, vegetation is more species-rich. Compared to a simple green roof, there is a wider range of vegetation stands - from sunny to half-shady with sunlit spots [10].
2) Thanks to the reduced sun exposure, the green roofs evaporation rate is lower. As a consequence, the shading reduces the drought stress for plants, especially during low-precipitation periods [10].

4. Installation of GRIPV on a high-rise estate in Hamburg, Germany

After having elucidated the potential of GRIPV in the previous chapter, on the following pages we are going to present a comparison of three different roof configurations - black roof (existing), retention roof and solar green roof – on a forty-year-old high-rise estate in Hamburg, Germany. In the introduction, the context, the study site as well as the climate are briefly introduced. Subsequently, the dimensioning as well the investment costs of each roof typology are delineated. With the aid of various calculations, the different roof configurations` impacts on stormwater management are assessed. Furthermore, the PV output has been calculated for the black roof and then compared with the GRIPV`s improved output due to the PV/plant interaction. In a discussion, the innovation potential, the beneficial effects as well as the limitations of such a project are described and completed with a conclusion.

4.1 Introduction

4.1.1 Context and study site

The analysed high-rise complex is called Kirchdorf Sued and is located on the island of Wilhelmsburg, approximately 12km away from Hamburg‘s inner city [12]. As shown in the diagrammatic cross-section (Fig. 2), the island`s terrain is very flat and situated about 1m above normal, whereas the mean high water of the tide-dependent river Elbe is about 2.20m above-normal. In order to make the island habitable and protect it from extremely high water levels as well as storm tides, dikes with a height of about 7.90m above normal have been built all around the island. The water regulation system is highly complex and consists of pumps, tidal gates and a network of interlinked ditches [13]. Amongst the different challenges on water management related topics mentioned in the study “Sustainable Water Management in the City of the Future” [14] the following are the ones, which could be mitigated by the integration of green roofs as a part of a water sensitive urban design strategy: 1) flood risks along the Elbe river and the North Sea, 2) flash flooding caused by stormwater run-off, 3) limited capacity of the existing sewerage system.

Due to its location in a flourishing harbour district, Wilhelmsburg has developed from a rural community into an industrial and residential district with a conglomerate of various housing typologies

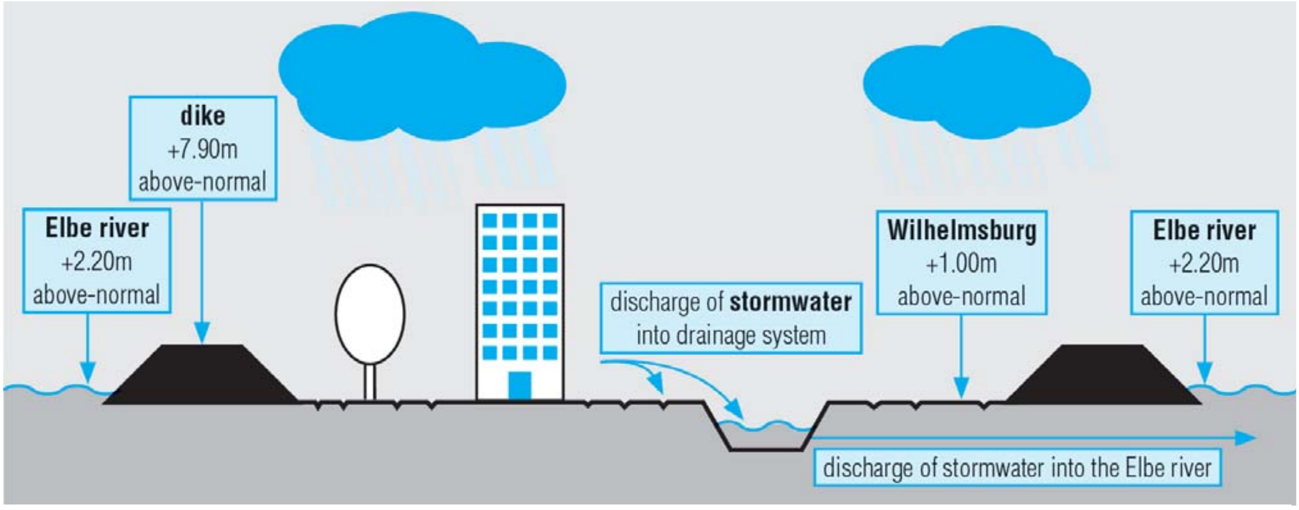

Fig. 2: Brief overview on the island`s water regulation system // Source: [13] // own graphic.

and manifold land uses. However, in 1962, a disastrous flood event has hit the island, resulting in a rapidly declining social and economic situation [14]. Nonetheless, between 1974 and 1976, the housing complex of Kirchdorf Sued has been constructed in the south of the island [12]. In 2012, 6‘238 inhabitants lived in the settlement - this corresponds to 17‘224 inhabitants per square kilometre [15]. Nowadays, Kirchdorf Sued belongs to Wilhelmsburg‘s disadvantaged neighbourhoods with a high unemployment rate, low-income levels, a high ratio of social security benefits recipients and an above-average proportion of foreigners [14].

4.1.2 Climate

Hamburg has a warm humid continental climate, which is influenced by its proximity to coastal areas, the seas as well as by nearby wetlands. The annual average temperature is 8.5° C. January is the coldest month with a temperature of -0.2° C, July the warmest month with a temperature of 17.3°C. The average rainfall is 738 millimeters per year. The lowest precipitation occurs in February (42 mm), and the highest one in August (79 millimeters) [16]. Fifteen minutes rainfall intervals have precipitation rates that vary from 6.3 mm (every six months) to 27.0 mm (100-year event) [17]. Due to the very low permeability of the soil, the infiltration amounts to only 25mm/year. Hence, a large part of stormwater remains on the surface and has to be diverted by the drainage system. Furthermore, the expected global climate changes will impact the local water balance. Especially the number of extreme events will increase and require new water management techniques in order to deal with the limited capacity of the existing sewerage system and the danger of flash flooding caused by stormwater runoff [14].

4.2 System definition, comparison and results

4.2.1 Computation of net areas

The built area of the housing complex corresponds to 41’745 square meters, whereas the area of the plot amounts to 257’483 square meters [18]. Hence, the building density amounts to 16.2 (%). For means of accessibility, 5% of the roof’s surface has been subtracted. Therefore, the net green roof area covers 39’657.4m^2. For means of circulation in between the PV panels, an additional 10% of the area has been subtracted from the net green roof area: The remaining 35’482.9m^2 are the net useful space for the PV system (Fig. 3).

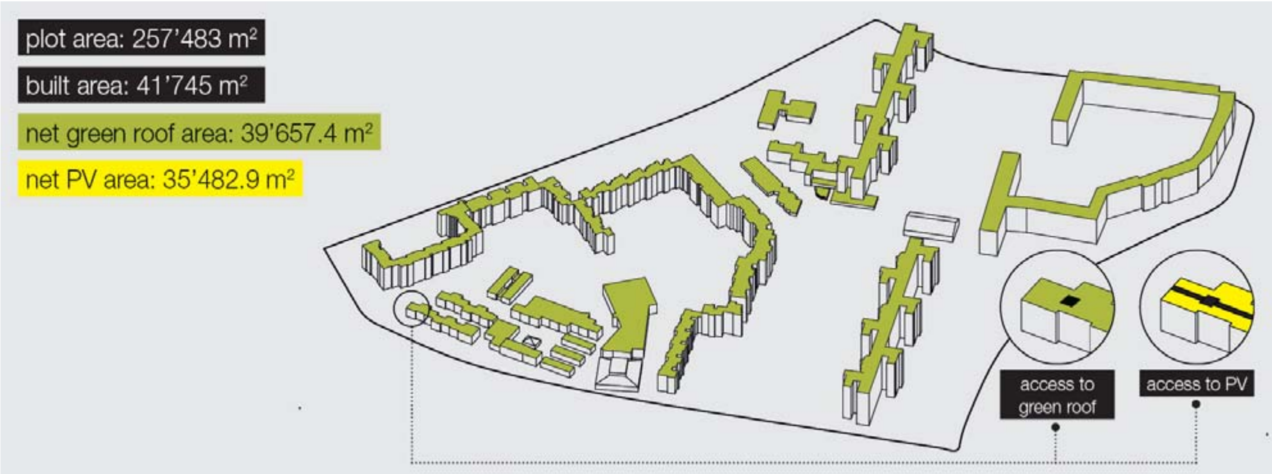

Fig. 3: Overview on the computation of the net areas // own graphic.

4.2.2 Comparison of three roof configurations in terms of discharge coefficients and capital cost

Taking the statistics of 15 minutes rainfall event [see 23] we calculated how much rainwater accumulates on the built area. Depending on the recurrence interval, we figured out that in case of a 15 minutes rainfall event, the water accruing on the flat roof buildings area varies between 375'701.4 liters (yearly event) and 1'014'393.8 liters (50 years event).

By multiplying these results by the coefficient of discharge ψ of the different roof typologies, it is possible to calculate how much water is directly discharged into the municipal sewage system. Looking at a yearly rainfall event, with the existing situation (black roof) the water discharged corresponds to more than 330'000 liters in 15 minutes, whereas a solar green roof releases about 169'000 liters, and a retention roof with meander a bit more than 3'700 liters in 15 minutes.

Differing from the existing black roof, which discharges the water almost immediately and therefore puts the drainage system under enormous pressure, the retention roof has a potential temporary storage capacity of 1'586'294.8 liters (40 l/m^2), and the solar green roof - a roof that is compatible with the installation of a PV system - has a temporary capacity of 991'434.3 liters (25 l/m^2). Looking at the rainfall event that happens every 50 years - where about one million of liters fall on the analysed flat roofs within 15 minutes - it is possible to observe that while the solar green roof is nearly capable of storing the accruing stormwater, the retention roof's temporary capacity is not yet fully exploited.

Thinking about the costs of installation and costs of maintenance, we have done a comparison between the costs of a black roof, a retention roof and a solar green roof over a lifespan of 50 years taking into consideration financial incentives and water taxes (see [19]), see [20]). Interestingly, the cost of a retention roof is the lowest (about 2'537'000 € in 50 years), whereas a black roof would cost about 2'637'000 € and a solar green roof 3'640'000 € (excluding PV system). Even though the solar green roof has the highest cost of installation, it has to be considered the fact that energy produced in situ could help to reach the payback period within a few years only.

4.2.3 Photovoltaic system - yearly electricity generation and payback periods

Taking into account the local premises for an efficient PV system - annual average irradiation, solar altitude in winter, tilt of the PV panels, performance ratio of PV - it has been computed that if on every flat roof of the high-rise complex a PV system were mounted, a system with a kilowatt power of 2’175 could be installed. Therefore, the yearly electricity production would be 1’801’784 kWh. Assuming that for one household the electricity need is equal to 3’010 kWh/a, that would be enough to cover the electricity demand of almost 600 households, meaning of about one fourth of Kirchdorf Sued`s households (26%).

According to Fraunhofer Institute, the total installation costs for a PV a plant is on average 1’350 €/kWp [21]. Therefore, the total costs of the PV system would be 2’936’817 Euro. Taking into account the local feed-in tariffs (0.1095 €/kWh in December 2014 [22]) it would be possible to recover the installation costs in approximately 15 years, while if the energy were used and resold in situ at the ordinary electricity price of 0.285 €/kWh, the initial costs could be recovered in about six years. According to Moore and Post, it is possible to assume that the yearly maintenance costs are 0.1% of the installation costs, meaning that the yearly expenses due to maintenance would account to circa 3’000 € [23].

4.2.4 Adopted Scenarios of PV output increase due to PV / plant interaction

As already discussed in chapter “Green Roof Integrated Photovoltaics”, the benefits of such combined technologies are manifold. On the basis of a comparative study by Lamnatou and Chemisana [5], an overview of a possible PV output increases due to the PV/plant interaction is shown (Fig. 4). Although scenario 1 describes the lowest improved PV output (circa 46’000 kWh), it is still possible to provide electric power to 15 households more. Scenario 2 represents the highest efficiency increase (circa 150’000 kWh/a), which would lead to 49 additional supplied households. Furthermore, the payoff time is remarkably reduced and amounts to 13.7 years (instead of 14.9 if installed on a black roof). The declared efficiency enhancement of an official GRIPV provider [9] is situated approximately in-between the findings of other studies.

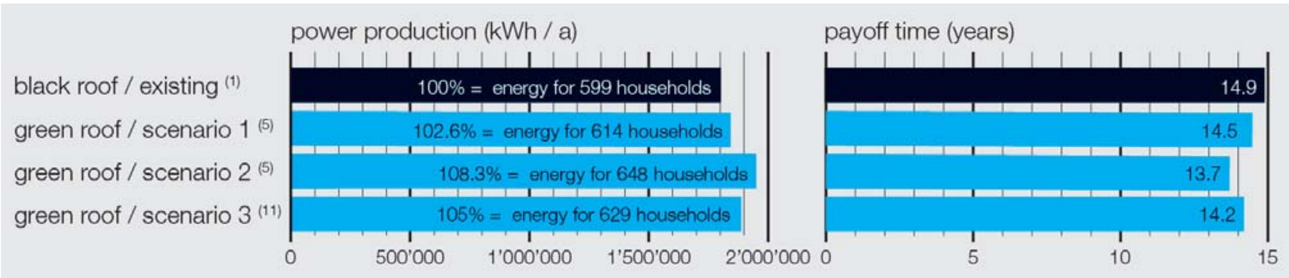

Fig. 4: Comparative evaluation of power production and payoff period. The PV / Plant interaction leads to increased PV output and consequently shorter payoff periods. Source: findings about increased PV output [5] and [9] // own graphic.

5. Discussion

5.1 GRIPV`s innovation potential

During our analysis we realized, that green roofs - be it retention or solar green roofs - are both equipped with convincing advantages. While the first one`s focus lies on the retention of stormwater, the second one is combined with an in situ power production. While studying the single layers of each roof, we were wondering, if the solar green roof`s standard drainage layer could be replaced with a highly retaining one. Hence, the solar green roof would not only produce electricity, but simultaneously feature an excellent discharge coefficient. Because no literature or even studies could be found, we decided to get directly in contact with a Green Roof service provider [24] to understand the current state of research. According to experiments done by the service provider, it would be possible to place the solar module bases on backfilled meander boards. Based on their analyses, the backfilled drainage boards would feature a discharge coefficient ψ of about 0.28 to 0.35. Thus, compared to the standard solar green roof (ψ = 0.45), this coefficient is significantly lower - meaning that the water retention is higher. Furthermore, the remaining roof surface could also be laid out with this highly stormwater-retaining drainage boards (instead of the standard drainage layer) and, therefore, lower the entire systems discharge coefficient. However, so far there are still some issues to be solved before the entire roof`s discharge coefficient can be reliably measured, and such a system build-up could enter the market.

5.2 Beneficial effects of GRIPV

With the aid of the calculations, it has been possible to dimension a system that could work satisfactorily - also thanks to the synergies created by its components. As already described previously, the high-rise complex`s inhabitants, as well as the island`s drainage system, would benefit from an installation of GRIPV. Among the most important beneficial effects are: 1) partial reduction of the area`s water stress caused by stormwater run-off, 2) reduced discharge into the municipal sewerage system, 3) in-situ generation of renewable electricity, which could cover the demand of about 26% of the settlement`s households, 4) payback period within an acceptable time span.

5.3 Limitations and uncertainties

The results of this study are only a first estimation and can be affected by various uncertainties. Given the fact, that we assumed that the existing flat roof is not only capable of supporting the additional load of a solar green roof but is also free of vertical volumes (chimneys,...). Thus, before the project could be implemented, the fundamentals have to be collected and then carefully analyzed. The calculations and comparison of increased PV output due to the PV/plant interaction were assumptions taken from studies, which refer to different conditions (climate, PV efficiency,…). Due to the lack of appropriate literature, it would be worthwhile to review the indicated increases in PV performance in regard to the analysed context (e.g. local climate data and building orientation).

During this research, we came across a study, which was carried out in one of New York’s poorest districts, the South Bronx. Thanks to a cooperation between the Columbia University and a local high school, some of the economically disadvantaged students were involved in an experiment about green roof integrated PV canopies: They not only helped to design and construct the model homes but were also involved in data acquisition, its analysis and the subsequent presentation of findings. According Perez et al., the experimental learning supported the students in breaking the poverty cycle. Furthermore, the fundamentals about renewable energy have been taught to the next generation of knowledge leaders [11]. Also in Kirchdorf Sued a similar study could be carried out - it would be interesting to do further researches about the various synergies of GRIPV as well as to test the solar green roof with a meander drainage layer. Due to the fact, that many of the inhabitants are rather underprivileged, and the settlement is not having the best image in the remaining city, such a project could be a real chance to create something, whose whole is more than the sum of its parts - not only the GRIPV technology would benefit from more substantial findings, but also the settlement and its inhabitants.

Furthermore, this fascinating technology involves a wide range of different parties. Hence, the elaboration of details as well as the implementation of such a project requires careful planning and a well-functioning communication right from the beginning on. Last but not least we consider the accruing costs as a crucial barrier to installing such a solar green roof - besides the already costly PV panels, also the system build-up is significantly more expensive than the one of standard green roofs. The estimated costs of a retention green roof amount to approximately 22 Euro/m², whereas the solar green roof costs about 50 Euro/m². We are not quite sure from where this exorbitant surcharge is originating - is it the cost for innovation or just the additionally required material? However, we were glad to realize, that the calculations revealed, that the retention green roof seems to be a rewarding investment - not only for ecological considerations but also for economic ones.

6. Conclusion

Sustainable development is facing a vast number of multifaceted challenges. To progress toward a post carbon society, innovation is necessary. In order to create prospective sustainable solutions, we have to move on from stagnant, rather unilateral mindsets. Therefore, innovations are required, which are based on multi-disciplinary thinking, research and practical implementation.

For this paper, we aimed to bring together two topics, which are usually taken into isolated consideration. Thanks to the analysis, which included a desk study about the current state of research as well as an exchange of information with a green roof provider, it has been possible to gain a multifaceted overview on green roofs as well as on PV system. Although the results are associated with some uncertainties, the beneficial impacts as well as the innovation potential are remarkable and have shown, that green roof integrated photovoltaics can be an essential puzzle piece on the path to sustainable urban development.

Even if various studies have approved the mutual benefits of solar green roofs, further investigations and experiments are required to provide reliable information. Not only in order to clarify the variety of heavily differing study results but also to discover the yet uncovered innovation potential.

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Guiding the building stock to a post-carbon future

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Summary

Taking Germany as an example, this paper describes a possible strategy to make the building stock of a country climate neutral. The strategy supports existing policies. It includes elements of information und target setting and focuses on creating effective financial incentives using a “push and pull principle”. The recommended strategy takes into account building stock data, the long-term need for climate action (decarbonisation) and barriers impeding ambitious building refurbishments.

Keywords: building stock, strategy, climate neutral, energy efficiency, renewable energies

1. Introduction

Climate change is one of the major challenges we are currently facing. The development of low-carbon strategies is essential. The buildings sector is responsible for approx. 40% of the total energy consumption of the European Union. Renewable energies are available to a limited extent only; this increases the priority of energy savings and energy efficiency improvement. Energy refurbishment of the building stock is a key component of ambitious climate action strategies. This paper presents a strategy for making the building stock climate neutral, using Germany as an example [1]. The strategy focuses on a long term goal underpinned by several regulatory instruments.

2. Methodology

Measured data from energy statistics showing the development of the building stock are analyzed in terms of influences and restrictions. The long-term need for ambitious climate action and its implications for the building stock are described. Based on this, targets for the building stock can be defined and an effective policy approach derived.

3. Energy consumption and CO_2 emissions of the German building stock

Basic data on the end-use energy consumption for space heating and water heating are provided by energy statistics. CO_2 emissions can be derived by applying emission factors. Both show large variations: Energy consumption decreased from 2005 to 2014 by 16.3 % to 761 TWh; CO_2 emissions decreased by 17.4 % to 199 Mt CO_2 (see figure 1 on the left). For residential buildings, which account for roughly 2/3 of the energy consumption of buildings, the changes are stronger: Energy consumption decreased by 17.9 % to 500 TWh; CO_2 emissions decreased by 18.6 % to 154 Mt CO_2 in 2014 (see figure 1 on the right). The increasing gap between energy consumption and CO_2 emissions can be interpreted as a slow shift towards low(er) carbon fuels like gas and renewable energies. However, temperature adjustment shows a much lower reduction of energy consumption (by 2.9 %; 890 TWh) and CO_2 emissions (by 4.4 %; 232 Mt CO_2). So the reason for energy and CO_2 savings can be seen to lie more in favourable weather conditions than in systematic improvements of the energy performance of buildings. Another impeding impact comes from increasing living area, which increased from 1996 to 2013 by 16 % [2].

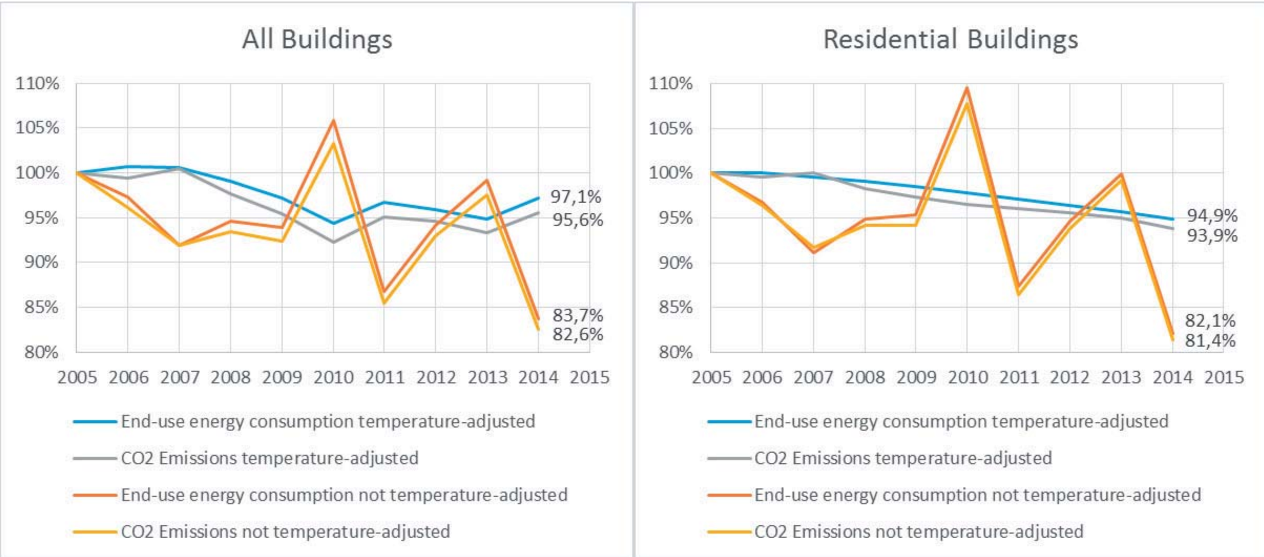

Fig. 1 Change in end-use energy consumption and CO_2 emissions for space heating and water heating of all buildings (left) and residential buildings only (right) in Germany. Based on [3].

4. Future situation

4.1 Existing targets

In 2010 targets were set by the German government in its “Energy Concept”, which were confirmed and refined in the framework of the “Energiewende” (energy transition) and the Climate Action Programme 2020 as well as in the National Action Plan on Energy Efficiency [4]: Targets were set for the reduction of GHG emissions and the use of renewable energies, but also for energy efficiency and buildings. Table 1 shows the relevant targets and the progress made towards them by 2013.

Table 1: German “Energiewende” targets (excerpt) for 2020 and 2050 and recent status in 2013. Based on [2].

Category	2013	2020	2050
Greenhouse gas emissions (vs. 1990)	-22.6 %	-40 %	-80 to -95 %
Energy efficiency (vs. 2008)			
Primary energy consumption	-3.8 %	-20 %	-50 %
Electricity consumption	-3.2 %	-10 %	-25 %
Buildings (vs. 2008)			
Non-renewable primary energy demand	-3.6 %	-	-80 %
Heating demand	+0.8 %	-20 %	
Energy-related refurbishment rate	ca. 1 % p.a.	2 % p.a.	2 % p.a.

One challenge is that the policy targets are not backed by existing data. For example, end-use energy consumption is used as an indicator for heating demand, but is not included in official statistics. Looking at the above figures, it is obvious that it will be difficult to achieve the 2020 target of reducing the heating demand by 20 %. It is not clear from these data if primary energy demand of buildings is on track due to the long period until 2050. The refurbishment rate is to indicate the activity in energy-related refurbishments but is both very difficult to assess and currently still too low.

4.2 Implications from climate action

To keep the impact of climate change within tolerable limits, the increase in global temperature needs to be limited to a maximum of 2 °C or less. To achieve this the CO_2 concentration in the atmosphere must be stabilized at 450 ppm. Given the responsibility of industrialized countries, they must reduce their overall CO_2 emissions by 95 %. For Germany, this means emissions of 1 t per capita, which is already exhausted by industrial and land use emissions etc. So the CO_2 emissions of the energy system have to be reduced to 0 t CO_2 – and that includes those from buildings as well [5]. This kind of decarbonisation has recently been backed by the Paris agreement on climate change.

Decarbonisation of the building stock requires improving the energy efficiency of buildings as far as possible and using only renewable energies for heating and cooling. In practice, the lifetimes of building parts have to be considered: Measures on the building envelope have lifetimes of 30 to 40 years, whereas heating, ventilation and cooling (HVAC) equipment is exchanged after 15 to 25 years. Most HVAC equipment will be changed twice until 2050. It can be adapted to a carbon free energy system in two steps until 2050. In contrast to this, building envelopes will be improved only once until 2050. In order to avoid additional costs for later corrections or the installation of additional renewable energies they have to meet long-term requirements in one step only. Effective climate action policies have to take these lifetimes and improvement cycles into account when addressing the decarbonisation of buildings.

5. Barriers

There are a number of financial and non-financial barriers to tapping existing saving potentials in the building sector [6]. Achieving the above-mentioned targets substantially depends on the willingness of building owners to invest in energy-related improvements to their properties. In many countries a large share of homes is owner-occupied. These barriers can be multiple, for example lack of information amongst building owners, risk aversion, financial constraints, lack of motivation, and individual expectations. Relevant barriers also include lack of technical know-how, knowledge and experts and poor enforcement of regulations [1].

Germany supports building owners through financial support programmes (e.g. subsidy schemes for investments in environmental protection and energy efficiency by the KfW Group and the market incentive programme for renewable energies, MAP). These support programmes are financed from public budgets. This involves the problem that the budgets for these support programmes are determined by annual budget negotiations. Thus the funds are not sufficient to stimulate the dynamics needed to transform the buildings sector into one that is more or less climate-neutral. In addition political discussions about the financial scale of the programmes and frequent changes in their conditions up to and including the temporary suspension of support funds lead to uncertainties. The building owners are often uncertain whether they will receive support at all and under what conditions. This is problematic in case support is not approved until the refurbishment measures have been completed; the house-owners have to bear the full risk of advance payments [7].

6. Strategy

6.1 Principles

The strategy for a climate neutral building stock by 2050 combines flexibility and reliability. It has to address multiple obstacles like low awareness, risk aversion, financial restraints and individual expectations of building owners etc. as well as the question of how to connect buildings to a future carbon-free energy system. The starting points for the strategy are the two conventional types of regulation currently used in this context: regulatory obligations and governmental support programmes (subsidies). Furthermore tax and other fiscal instruments are considered. The strategy can take technical and political framework conditions into account and has four key elements (see figure 2):

1) Energy performance certificates are used to describe the current energy efficiency status of a building; this information is gathered centrally to get an overview of the building stock and its changes (see chapter 6.2).
2) A long-term target and intermediate targets are defined both for individual buildings and for the whole building stock. Achievement of the targets is monitored (see chapter 6.3).
3) Individual renovation plans are drafted for individual buildings and for whole quarters (see chapter 6.4).
4) To create financial incentive in the short term energy tax rates are increased, followed by the introduction of a “building climate levy” in the medium-term (see chapter 6.5). This policy instrument is examined in terms of its national and European legal viability and is evaluated according to functionality criteria.

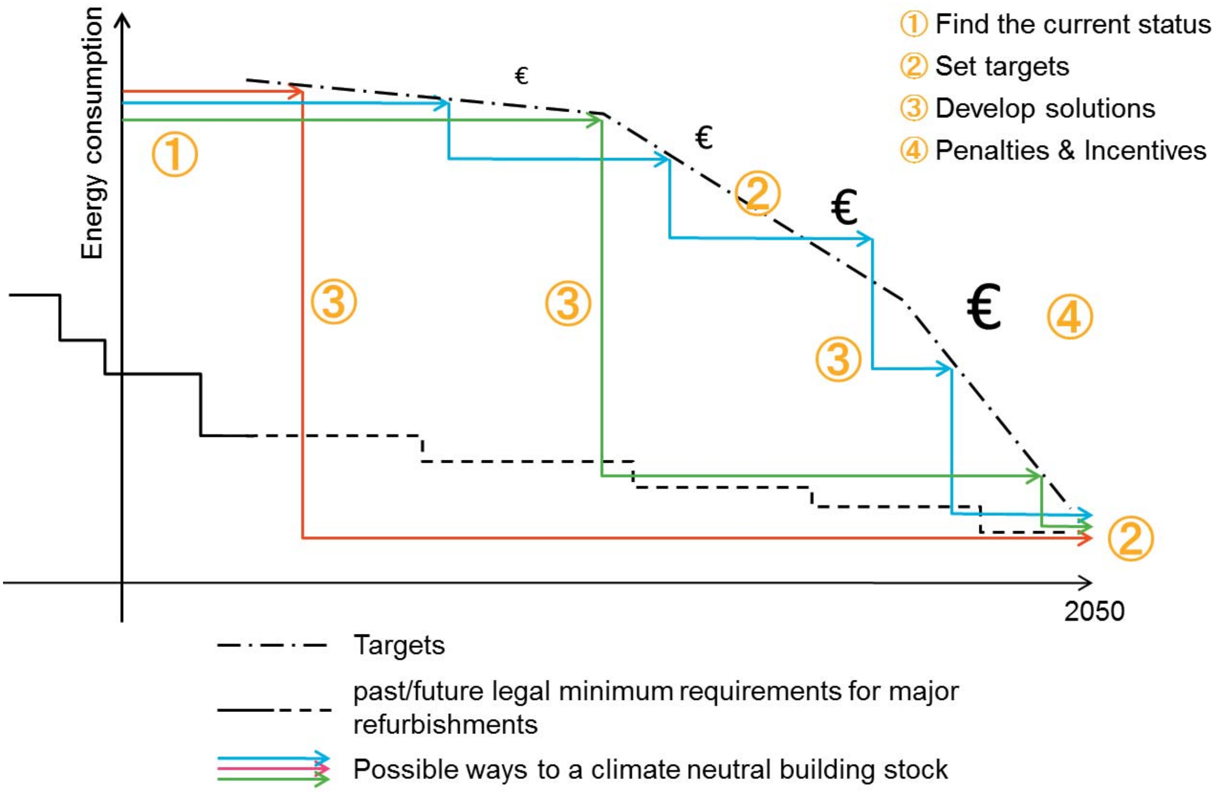

Fig. 2 Principle of a strategy for making the building stock climate neutral

6.2 Current status

Energy performance certificates should be used to describe a building's current energy efficiency status as a starting point. The certificates should be based on calculations of the energy demand since the goal of the strategy is to transfer the building stock to a constructional and technical state which ensures that the climate action targets are achieved independently of consumer behavior. Parameters of the overall performance of a building should be directly linked to CO_2 abatement. Key information from the certificates should be gathered centrally and anonymously in a database to get an overview of the building stock and its development over time.

6.3 Setting targets

Description of the current status is complemented by the setting of a long-term target as well as several intermediate targets – both for single buildings or quarters and for the whole building stock. Targets make it possible to check whether both single buildings and the whole building stock are on track based on the information on the current status gathered centrally (chapter 6.2). The long-term target enables building owners to choose appropriate measures when planning to improve the building envelope or carrying out major renovations. It also enables the legislator to align its instruments like building codes or funding programs. Intermediate targets show whether further action is needed in the short or medium term. Targets should be both reliable and (if needed) adjustable.

6.4 Develop solutions

Individual renovation plans have to be drafted for single buildings and for quarters. They bridge the gap between the current status of a building or quarter (chapter 6.2) and the targets (chapter

6.3). They put building owners in a position to decide on appropriate renovation measures which put a building in a state to meet

- the next intermediate target, followed by further single measures in future (see figure 2, blue line),
- the long term target in one step by applying a very ambitious major renovation (see figure 2, red line),
- a mid-term intermediate target by applying a major renovation followed by another measure like installing a ventilation system with heat recovery in the long term to achieve the long term target (see figure 2, green line), or
- any other combination of these three principles.

This approach gives building owners maximum freedom to choose the time and kind of improvement measures according to their financial situation or the period they plan to use the building. Simultaneously this approach ensures that also partial improvement measures are in line with the long term target of a climate neutral building stock.

6.5 "Push and pull" incentives

A "push and pull effect" is supposed to increase the rate of energy refurbishment of buildings: A "push" incentive by tax or levy supports energy refurbishment measures in order to reduce the financial burden on affected building owners. A "pull" effect is created by generating additional financial resources to finance funding programmes for early and ambitious refurbishments continuously and independently of the uncertainties of public budgets [6]. In addition, a legal right to obtain support for ambitious energy refurbishment measures should be introduced to give building owners sufficient security for planning.

Two steps are recommended to implement those instruments:

As step one, a legal right for house-owners to receive support for energy refurbishment should be introduced. That way house-owners willing to refurbish are guaranteed to receive financial support for their renovation project ("pull" incentive). At the same time a surcharge should be added to the energy tax for fossil fuels for heating that are put on the market ("push" incentive). The additional tax revenue from the energy tax levied on fossil fuels is fed into a support scheme earmarked for the energy refurbishment of existing buildings. Both can be realized within a relatively short time frame. They allow to bridge the time gap until a more sophisticated approach like a "building climate levy" is implemented [8].

As step two, a "building climate levy" ("push" incentive) should be implemented. It can replace the energy tax surcharge. The levy requires house-owners to pay for a low efficiency level of their house. The amount of the climate levy should be related to the energy performance of the building compared to the intermediate targets (chapter 6.2). The introduction of the climate levy requires a classification of buildings according to standardized characteristics. At the same time building owners become aware of the current efficiency status of their house. Concurrently they can prove the existence of a better status. In view of the very complex circumstances of this issue, also a simplified building typology could be used for the classification (chapter 6.3); simple parameters can be used such as age, cubic content, building type, construction, purpose - as long as buildings can achieve a more favourable classification on presentation of appropriate proof of adherence to better energy performances (preferably based on calculation of energy demand). Some lead time is needed to implement this, so that the building levy could enter into force for example after a period of about five year. Further research is needed to identify suitable parameters for this purpose [7]. The generated revenues from the “building climate levy” are fed into a special public support fund (“pull” effect).

The building-related climate levy has the advantage that a targeted incentive is produced. The obligation to pay the climate levy has a direct effect on the building owners who are responsible for taking the decision to implement the energy refurbishment of their buildings. The climate levy has the basic disadvantage that a classification of residential buildings according to their actual energy performance standard would be necessary. Establishing such a system is likely to take several years. Its costs are justified in view of the huge significance of the buildings sector to climate protection. Another advantage of the classification of buildings is that this would create a common, uniform basis for an adequate valuation of the energy performance of a building on the housing market, which has not been sufficiently the case up to now in Germany [6].

7. Discussion

This policy strategy has not yet been implemented. Nevertheless we believe that its advantages outweigh the drawbacks. It is a recommendation for an effective set of policy instruments including a time frame for its implementation in a legal and functional way. However, in the light of the need for climate action, it is important to start the development of ambitious strategies and to discuss and refine them. Also, further research is needed in multiple dimensions:

- There is still a lack of data: Buildings aren’t an energy sector, so little/scarce data are available on energy use but also on energy refurbishments.
- Methods have to be developed to define levels for individual buildings which lead to the desired target for the total buildings stock.
- The actual effect of this strategy has to be proven before applying it, for example in field tests or simulation games. This would result in recommendations to improve the strategy.

8. Conclusion

The strategy aims to increase the rate of energy refurbishment. It avoids obliging building owners to carry out renovations. It incorporates a “push and pull effect”: A “push” incentive supports energy refurbishment measures in order to reduce the financial burden on affected building owners. A “pull” generates additional financial resources to finance funding programmes for early and ambitious refurbishments continuously, and independently of the uncertainties of public budgets. In addition, a legal right to obtain support for ambitious energy refurbishment measures should be introduced to give building owners sufficient security for planning. To bridge the time gap until a “building climate tax” is implemented, energy tax rates could be increased in the short term and the revenue fed into funding programmes.

Finally the policy instruments suggested here constitute only one part of a more comprehensive set of policies. The key instruments must be accompanied by various and target-group-specific measures (e.g. including information, motivation, qualifications, quality assurance) in order to effectively and efficiently tap the substantial saving potentials in the buildings sector.

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Hempcrete from cradle to grave: the role of carbonatation in the material sustainability

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Summary

The goal of reducing buildings impact to the environment is achieved by minimizing the energy consumption and through the employment of sustainable materials. However, the sustainability of building materials is assessed too many times considering a single phase of the material lifecycle (e.g. the use phase for good insulating materials). Even “LCA” studies focus sometimes on a single stage of the lifecycle, but this approach is particularly wrong for materials that improve or reduce their environmental performance during the operational phase or at the end of the building’s life. This is the case for materials containing lime, whose strength and sustainability increase theoretically along with the carbonatation process. An innovative building material containing lime is the hempcrete brick: a non-structural composite material obtained from a mixture of hemp shives (woody core of the hemp stalk) and a lime based binder; this material shows good thermal performances (λ: 0.07 W/m·K) and moisture buffering capacity. LCA studies about hempcrete materials either leave out the carbonatation process from the assessment or assume that lime is fully re-carbonated in the use phase of the building. The goal of our study is to assess the real rate of carbonatation of hempcrete bricks in order to include the results in a thorough LCA study and to understand the weight this process can have in the overall sustainability of the material. The carbonatation rate has been evaluated on bricks produced by the Italian company Equilibrium Srl. The degree of carbonatation is evaluated through X-ray diffraction on samples extracted at regular intervals from the brick production up to 5 months. Carbonatation depth profiles are obtained too. Results show the importance of evaluating the behavior of a material in all the phases of the lifecycle and could be used for future LCA studies on hempcrete materials exposed to similar conditions.

Keywords: hempcrete, LCA, carbonatation, carbon footprint, building materials

1. Introduction

As recently reported [1, 2], the building sector accounts for about 32% of global energy use and for about 19% of energy-related greenhouse gas emissions. Therefore, in the field there is a consensus towards the reduction of non-renewable energy sources exploitation and mitigation of GHG emissions, which is promoting the search for alternative and less impacting materials to replace conventional ones [3]. Natural materials are one of these options, as they would allow the reduction of non-renewable resource depletion and of environmental impacts related to fossil fuel consumption. To this purpose, hemp is an industrial crop that suits perfectly the building sector requirements [4]; indeed, it is a natural product already used as construction material [5].

Hemp stem consists of a woody core surrounded by an outer skin containing long and strong fibres, and two main products can be obtained by its processing: hemp hurds (or shives) and hemp fibres. Hemp fibres are the most valuable part of the plant, and in the building industry they are usually used as insulation products, although Fibre Reinforced Concrete (FRC), a composite concrete material consisting of a hydraulic cement matrix reinforced with discontinuous discrete fibres dates back to 1960s [6]. However, the use of hemp fibre and shiv in concrete and cement mortars is being seriously considered by many authors [7-9].

On the contrary, hemp lime-based products have been extensively used as construction materials. Indeed, hemp lime composites started being used in France throughout the 1990s and now there are many examples of hemp lime constructions spreading around in other countries [10]. Hemp lime composite, often referred to as hemp concrete or simply hempcrete, is a building material formed from the mixture of hemp hurds as aggregate and lime based binders, which finds application for insulating walls or insulation layers for floors and roofs and, combined with a load bearing structure, for perimetral masonry.

In the recent literature, various mechanical properties have been tested on lab scale specimens: compressive strength, flexural strength, and flexural toughness among others. Clearly, mechanical properties strongly depend on the binder used and on the addition of fillers and aggregates. A summary of the mechanical properties of the hemp fibre/hurds lime/cement composites can be found in a recent review [4]. Recently, there has been also un upsurge of interest in thermal [11] and hygrothermal properties of hemp-lime concretes and buildings [12-16].

Few studies on sustainability of hemp-based building materials have appeared in the recent literature up to now [10, 17-19], and those considering specifically hemp lime products account for the CO_2 sequestered during lifetime as the maximum possible value, i.e. supposing full carbonatation of the lime binder. However, a recent study has highlighted that in hemp-based mortars with aerial and natural hydraulic lime mixes hardening is delayed because of an insufficient amount of water available to the matrix of the mixes from the start [20].

The aim of the study is to assess the environmental impacts of hempcrete bricks produced by the Italian company Equilibrium (www.equilibrium-bioedilizia.it) located in the province of Bergamo, and to understand the role that carbonatation could play in their LCA analysis.

2. Materials

The hempcrete bricks considered in the study are composed of dolomitic lime and hemp shives, with a ratio by mass binder to hemp of 1.3.

Hempcrete bricks can be used without the support of other materials: combined with a load bearing structure (pillars or frame), they can be used as a perimetral masonry. The dimensions of the bricks here considered are 50 cm x 40 cm (faces exposed) x 25 cm (thickness).

The bricks have very good insulation properties with a thermal conductivity of 0.07 W/m·K. Moreover, the bricks are resistant to fire, to frost, to insects and to rodents. They are reusable or recyclable at the end of the building life. Finally, hempcrete bricks have good acoustic and psychrometric properties.

3. Methodology

3.1 LCA

The LCA presented in this paper follows the methodology defined by international and European norms: ISO 14040, ISO 14044 and EN 15804. For the LCA anlysis' implementation the software SimaPro 8.0.5 was used.

3.1.1 Functional unit

The functional unit considered in this study is the square meter of non-load bearing wall made of hempcrete bricks. The overall heat transfer coefficient of the wall (U-value) is 0.27 $W/m^2 \cdot K$, equal to the limit imposed by the Italian law (D.M. 11 Marzo 2008 [24]) for retrofitted buildings in the area of Milan (Climatic zone E). The thickness of the wall is 0.25 m and both faces of the wall are supposed to be in contact with air.

3.1.2 Data quality and system boundaries

Primary data are used for the production phases inside the factory ("from gate to gate") and secondary data for the production of the materials used in the mixture of the brick. The impacts related to lime production are extrapolated from the Ecoinvent database. The environmental impacts related to the production processes of hemp hurds are taken from a previous LCA study on hemp cultivation [18]. The producing company supplied all the data related to transport and packaging processes.

The LCA considers the impacts related to the production phase of the wall and its use phase. The impacts related to the transport of the bricks on the building site and the erection of the wall are not considered. Even though the bricks can be reused as they are after the building demolition, the end of life of the bulding is difficult to forecast and therefore it was not considered.

3.1.3 Impact indicators

Three midpoint indicators are considered in the study: 1) CML-IA Baseline (7 impact categories); 2) Cumulative Energy Demand (CED, in MJ); 3) Greenhouse Gas Protocol (GGP, in kg CO_2-eq).

3.2 Carbonatation

The carbonatation of the hempcerte brick vs time was investigated via semi-quantitative X-Ray Powder Diffraction (XRPD) analysis. The phase composition of samples extracted at regular time intervals was studied, starting from the brick production up to 5 months (30, 75, 110 and 150 days). Carbonatation was investigated also as a function of the brick depth: at each time, 5 portions of brick were extracted at different depths (0-2, 2-4, 4-6, 6-8 and 8-10 cm), crushed and sieved to separate the binder fraction from the hemp. Figure 1 shows the brick used for the analysis and the hole left in the brick after the coring of the sample.

The XRD pattern of each fraction was recorded with a Bruker D8 Advance Diffractometer using graphite monochromated Cu $K\alpha$ radiation. The measurement interval was 10-50 ° 2θ, with measurement steps of 0.02 °2θ and a measurement time of 1 s/step. The peaks used for the semi-quantitative analysis were the *(001)* peak of $Ca(OH)_2$ at 2θ = 18.048, the *(001)* peak of $Mg(OH)_2$ at 2θ = 18.587, the *(104)* peak of $CaCO_3$ at 2θ = 29.406 and the *(200)* peak of MgO at 2θ = 42.917. These peaks were also recorded with a measurement time of 4 s/step to increase the counting statistics. The integrated intensities of the reported peaks were evaluated via peak profile fitting of the experimental data, performed with the software Topas+ 2.1 (Bruker AXS®) using a Pseudo-Voigt profile function. The obtained integrated intensities were used for the semi-quantitative analysis of phases using the the generalized Reference Intensity Ratios (RIR) method. Provided that all the phases are taken into account, the intensity of the peaks can be related to the amount of each phase in the mixture through the generalized RIR equation [25]:

$$\chi_\alpha = \frac{I_{i\alpha}}{RIR_\alpha I_{i\alpha}^{rel}} \left(\frac{1}{\sum_{k=1}^{n(phases)} \frac{I_{i,k}}{RIR_k I_{i,k}^{rel}}} \right) \quad (1)$$

where χ_α is the weight fraction of the phase α, $I_{i\alpha}$ is the integrated intensity of the i^{th} peak of the phase α, $RIR\alpha$ is the Reference intensity Ratio of the phase α respect to corundum (literature values were adopted) and $I_{i\alpha}^{rel}$ is the relative intensity of the i^{th} peak respect to the most intense peak of the same phase α.

The results of the semi-quantitative analysis of each portion was then used to evaluate the amount of calcium hydroxide and calcium carbonate at each depth in the brick and finally in all the brick body.

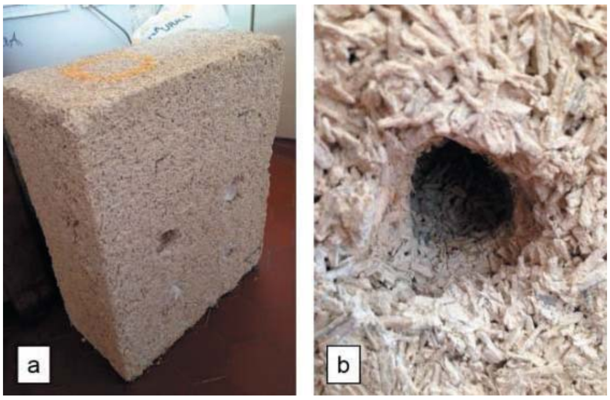

Figure 1: (a) Hemp brick sample, (b) hole left in the brick after sample coring

3. Results

3.1 LCA “from cradle to gate”

3.1.1 Hempcrete bricks production

The hempcrete bricks considered in the study are produced by the Italian company Equilibrium (www.equilibrium-bioedilizia.it), located in the province of Bergamo. Hemp is cultivated in the province of Turin by the company Assocanapa and the quarry of the dolomite is situated 320 km away from the bricks’ production site, in the province of Cuneo. Once arrived to the production site, the components of the mixtures are blended in a mixer with water. After the mixing process, the hempcrete mixture is pressed and the resulting bricks are arranged on shelves to cure and give them enough strength to be transported to the construction site and installed. Before the transportation, the bricks are wrapped in a thin film of polyethylene.

3.1.2 Greenhouse Gas Protocol

Figure 2 shows the results of the production of a square meter of hempcrete wall in terms of greenhouse gases. The method used is the Greenhouse Gas Protocol, developed by the World Resources Institute. The results show that the amount of greenhouse gas emissions in terms of kg of carbon dioxide equivalents due to the production phase are lower than the amount of carbon dioxide absorbed by the hemp during its growth through the photosynthesis process (CO_2 uptake). About 83% of the fossil CO_2 emissions are related to the lime production and in particular to the calcination process occurring in kilns at very high temperatures. The contributions of CO_2 emissions from biogenic source and the ones due to land transformation are negligible, as we can see in Figure 2.

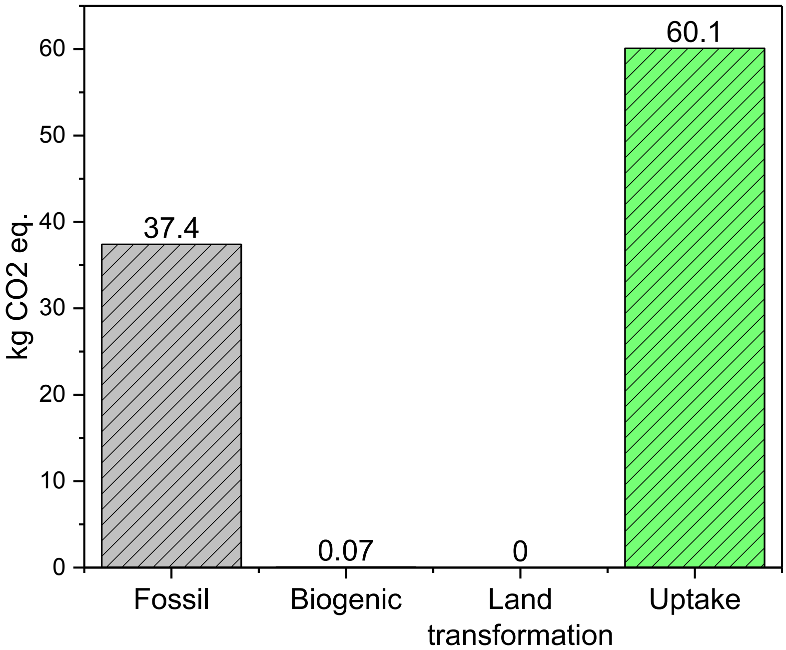

Figure 2: Greenhouse Gas Procol results (FU: 1 m^2 wall)

3.1.3 CML-baseline results

Table 1 shows the CML-IA baseline indicator results for the seven environmental impact categories required by the UNI 15804 to assess the sustainability of building products. As for the greenhouse gases' emissions, main contributions for all the impact categories except abiotic depletion derive from lime production processes. Depletion of abiotic resources is mainly due to the consumption of lead in the production process of fertilizers and to the consumption of uranium, used to produce part of the electricity consumed in Italy.

Table 1: CML-baseline indicator results

Impact Category	Unit	Hempcrete wall [1 m^2]
Abiotic depletion	kg Sb eq	2.24E-07
Abiotic depletion (fossil fuels)	MJ	304
Global Warming Potential (GWP100a)	kg CO_2 eq	37.4
Ozone Layer Depletion (ODP)	kg CFC-11 eq	3.35E-06
Photochemical oxidation	kg C_2H_4 eq	6.80E-03
Acidification	kg SO_2 eq	6.23E-02
Eutrophication	kg PO_4--- eq	3.80E-03

3.1.4 Cumulative Energy Demand

Figure 3 shows the results for the Cumulative Energy Demand method. The very high value of the energy from biomass is due to the significant presence of hemp in the product. It is important to underline that the binder-hemp ratio in the brick is in mass. Since hemp hurds' density is lower than lime's density, the volume occupied by the hemp in the brick is much higher than the one occupied by the binder. The contributions of the energy from nuclear and other renewable sources (wind, water and sun) derive from the consumption of electric energy in the brick manufacture and, therefore, from the Italian electricity generation mix.

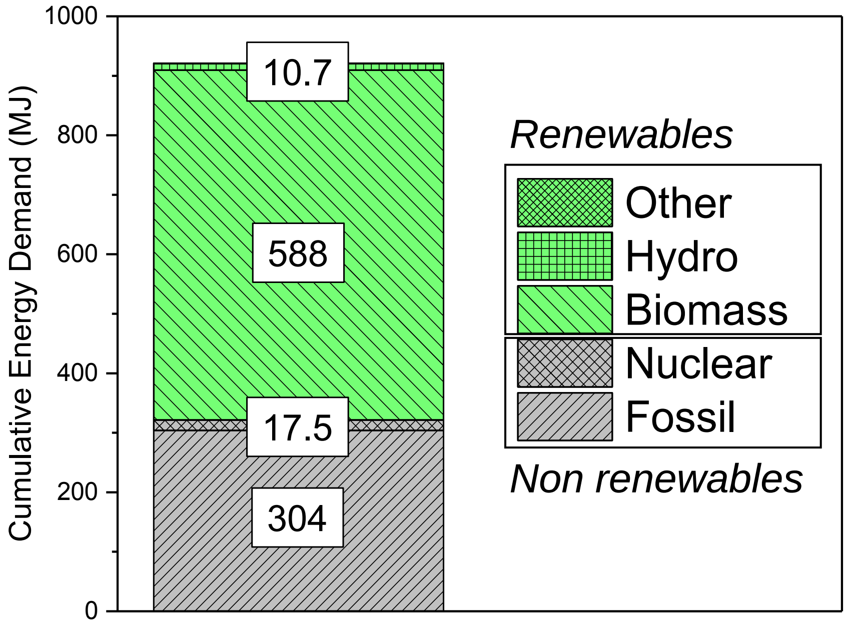

Figure 3: CED results

3.2 Carbonatation results

In each sample, the identified phases in the binder fraction are $Ca(OH)_2$, $CaCO_3$, MgO and $Mg(OH)_2$. The amount of each phase was quantified in the 5 fractions extracted at increasing depth (0-2, 2-4, 4-6, 6-8 and 8-10 cm) at each time interval (30, 75, 110 and 150 days). At each time, the amount of $Ca(OH)_2$ and $CaCO_3$ were considered to assess the extent of carbonatation in the hempcrete bricks.

Figure 4 reports the XRPD patterns of the binder at different depths after 75 days of ageing. Only the peaks of $Ca(OH)_2$ and $CaCO_3$ are indicated for sake of simplicity.As expected, the amount of $Ca(OH)_2$ increases moving from the surface layer to the inner layers at any aging time; after 30 days for example, $Ca(OH)_2$ is 47% at 0-2 cm depth and 62% at 8-10cm depth. $CaCO_3$ show an opposite trend (15% is found in the surface layer, and drops down to about 6% in the inner layer, at 30 days). Similar trends are found at any ageing time.

Figure 5 reports the amounts of $Ca(OH)_2$ and $CaCO_3$ in the brick as a function of ageing time. Analysing the carbonatation respect to age of samples, a significant transformation of $Ca(OH)_2$ into $CaCO_3$ is revealed in the outermost layer (from 47% $Ca(OH)_2$ and 15% $CaCO_3$ at 30 days to 14% $Ca(OH)_2$ and 38% $CaCO_3$ at 150 days). A similar behavior is observed in the 2-4 cm and 4-6 cm layers, but in a much lesser extent. In the innermost layers, instead the composition remains nearly unchanged up to the investigated ageing time. Therefore, in a 150 days timeframe, carbonatation appears to be significant only in the external part of the brick.

By integrating the results of each layer on the whole brick volume, the ratio of carbonatation with respect to the maximum possible carbonatation can be calculated; in this respect, Pretot et al. assumed that during the brick lifetime (a conventional period of 100 years is assumed [19]) a complete transformation of $Ca(OH)_2$ to $CaCO_3$ can be achieved. In a functional unit of 1 m^2 of wall with bricks of 25cm thickness with two sides exposed to air, the expected carbonation after 150 days is about 9% (i.e. 9% of $Ca(OH)_2$ has reacted with CO_2 to yield $CaCO_3$). Quantitatively, this means about 1.7 kg CO_2 adsorbed per m^2 of wall.

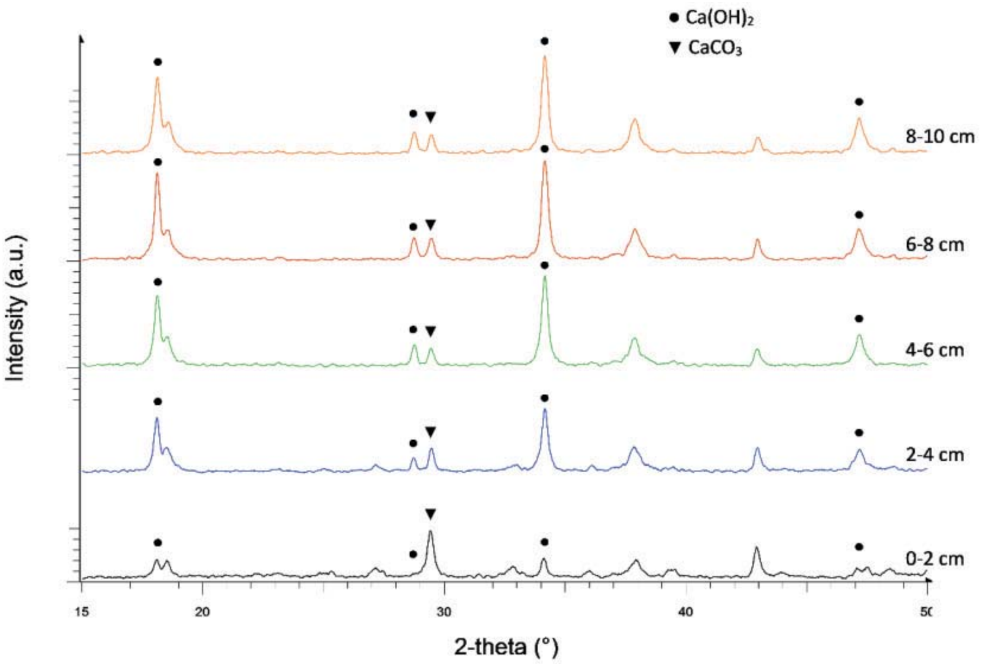

Figure 4: XRPD patterns of the binder at different depths after 75 days

Figure 5 shows the amount of $Ca(OH)_2$ and $Ca(CO)_3$ vs time. The points at day 0 represent the amount of the two chemical compounds before the process of blending (i.e. in the dolomitic lime). When water is added to the mixture, additional $Ca(OH)_2$ is formed from the chemical reaction between the dolomite and water. From the figure it is clear how the $Ca(OH)_2$ amount decreases with time, while $CaCO_3$ increases

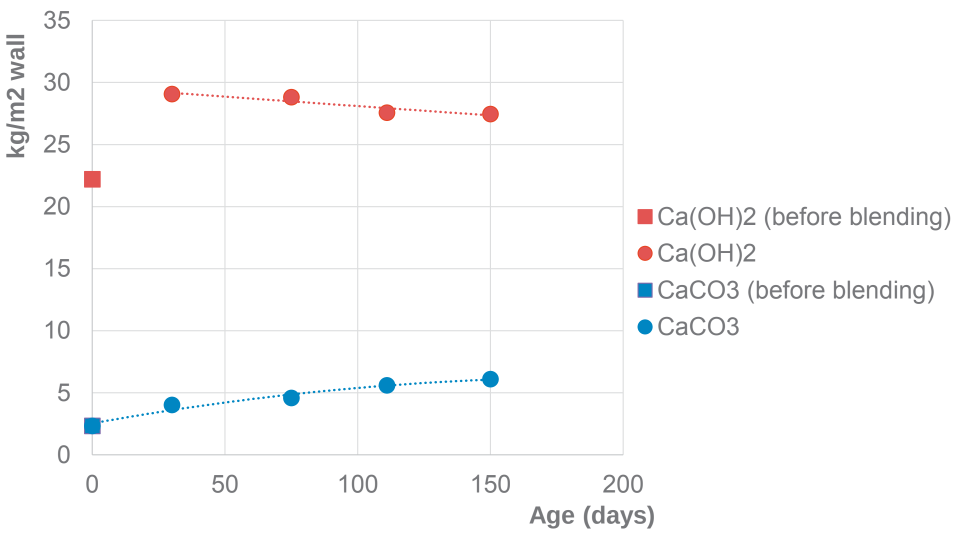

Figure 5: carbonatation m^2 wall vs time

3.3 Hemp brick wall operational phase

To extend the sustainability analysis of the hemp bricks wall from a “cradle to gate” perspective to a “cradle to grave” one, the operational phase of the system must be evaluated. Hempcrete is a recently developed material and very little is known about its durability. However, due to the presence of lime in the mixture, the mechanical performances of the wall exposed to air must increase along with the carbonatation process and, therefore, with time. Moreover, the material is resistant to fire, frost, insects and rodents. For the above-mentioned reasons, we consider that the wall does not require any maintenance during its operational phase. Furthermore, considering that the bricks can be reused as they are after the demolition of the building, no negative environemental impacts are added to the ones generated during the production phase of the wall. Even though we do not consider any further environmental impact during the use phase of the wall, the carbonatation process could generate environmental benefits. Through the process of carbonatation, the wall can absorb in fact carbon dioxide from the atmosphere and stock it in the brick for the rest of its lifetime. Knowing the amount of $Ca(OH)_2$ at the time of the brick production, it is possible to estimate the total amount of CO_2 that the wall could uptake during its lifetime. Moreover, thanks to the carbonatation analysis described in the paragraph 3.2, it will be possible to draw the profile of carbonatation of the wall with time. Since the brick we considered in this study is only 150 days old, it is too premature to draw the carbonatation profile of the material. However, thanks to the analysis already performed it is possible to estimate the amount of carbon dioxide absorbed by the wall in the first months and draw the first conclusions.

In Figure 6 is represented a comparison between the emissions of fossil CO_2 equivalents in the atmosphere throughout the lifecycle of the hempcrete wall and the total amount of CO_2 that the wall has removed in its lifetime from the atmosphere thanks to the photosynthesis and the carbonatation processes. In this way, it is possible to estimate whether the wall is neutral, negative or positive in terms of contribution to global warming. Figure 6 shows that, after the production phase, no further contribution is added on the stack of the fossil CO_2 eq. emissions. On the contrary, on the stack of the CO_2 uptake, the contribution related to the carbonatation of the bricks during the use phase of the wall appears. In the stack, two different contributions are added: the amount of carbon dioxide already absorbed by the wall after 150 days and the amount of CO_2 that the brick could absorb if all the $Ca(OH)_2$ would turn into $CaCO_3$ in the wall lifetime. In the first 150 days, 1.7 kg of CO_2 are already absorbed by each squared meter of hempcrete wall. The amount of CO_2 absorbed in the first 150 days is approximately 9% of the total CO_2 that the wall could absorb.

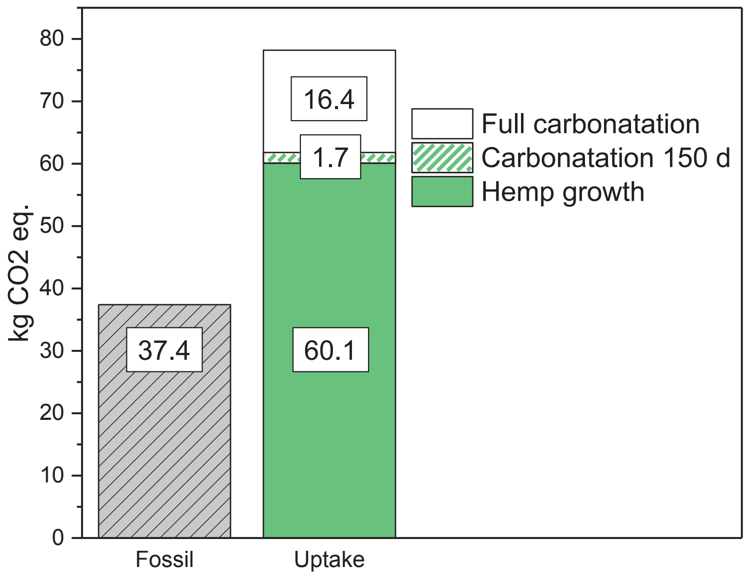

Figure 6: CO_2 fossil emissions vs uptake (FU: 1 m^2 hempcrete wall)

4. Discussion

Thanks to the X-ray diffraction analysis on hempcrete brick samples, it was possible to estimate the amount of CO_2 that a hempcrete wall in contact with air absorb in the first 5 months. After 150 days from bricks' production, the ratio in terms of greenhouse gases' emissions is 1.65 kg of CO_2 absorbed per kg of CO_2 emitted. The ratio could exceed the 2 kg CO_2 eq. absorbed/kg CO_2 eq. emitted if all the $Ca(OH)_2$ available in the brick carbonatated. Throughout its lifecycle, the hempcrete wall has a negative balance in terms of global warming potential and it is therefore acting as a carbon sink. Every m^2 of hempcrete wall can have a net positive balance that goes from 23 kg of CO_2 subtracted from the atmosphere (with no carbonatation) up to 41 kg (if the wall is fully carbonatated).

5. Conclusion

According to the results obtained some conclusions can be drawn:

- The LCA analysis of the hempcrete brick production (from cradle to gate) show that the main environmental impacts derive from the lime calcination process. The GGP results show that the amount of greenhouse gas emissions due to the production phase are lower than the amount of carbon dioxide absorbed by the hemp during its growth.
- The X-ray diffraction analysis of samples extracted from the brick at regular intervals allowed to obtain a quantitative evaluation of the carbon dioxide absorbed by the brick in the first 5 months. After 5 months 1.7 kg of CO_2 are already absorbed by each squared meter of hempcrete wall. In a functional unit of 1 m^2 of wall with bricks of 25 cm thickness with two sides exposed to air, the expected carbonation after 150 days is about 9%.
- Thanks to the results obtained with the carbonatation analysis, it was possible to extend the LCA study from a “cradle to gate” approach to a “cradle to grave” one. The LCA results indicate that throughout its lifecycle, the hempcrete wall has a net negative balance in terms of global warming potential. The wall can therefore act as a carbon sink, with a net balance that goes from 23 kg of CO_2 subtracted to the atmosphere (with no carbonation) to 41 kg if the wall is fully carbonatated.
- The carbonatation in the bricks' points distant from the surface exposed to air after 150 days seems null. Even though 150 days is a too short period to draw conclusions on the carbonatation profile of the material, the carbonation in the inner layers of the wall appears to be a very slow process. Moreover, the carbonatation process could be hampered if a plaster was used to cover the hempbrick wall.

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How Future-proof Is Your Campus? Sustainability in the Real Estate Management of Research Organizations

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Summary

Some of the well-known research institutions in Germany want to comply with their social responsibility and support sustainable development. They are seeking to enforce an integral concept for enhancing sustainability in their business operations and develop practical advices for sustainability management and reporting in line with the specifics and needs of non-university organizations. An example is the “LeNa” (Leitfaden Nachhaltigkeitsmanagement, sustainability management guidelines) project. It focuses on the development and evaluation of strategies for establishing a future-proof campus, including the corresponding performance measurement and sustainability reporting instruments. Other important aspects are the levels and fields of action, a workmanlike provision of information and tools as well as accounting, and discussion of existing and supplementary assessment criteria that are to be applied in a transparent and comparable manner.

Keywords: CSR - real estate management - campus development - sustainability assessment - sustainability reporting

1. Introduction

The decisions made at the UN Conference on Environment and Development in Rio de Janeiro in 1992 led to the Agenda 21 action program, in which the importance of science and universities to the implementation of sustainable development is described [1]. To implement sustainable development, a comprehensive modernization concept of society is needed, with economic as well as ecological and social objectives being considered. Education and research institutions fulfill four classical tasks in society: They create knowledge by scientific research, impart knowledge by basic and vocational education, disseminate knowledge by information and communication technologies, and they use knowledge with the help of innovative technologies [2]. Many activities to enhance sustainability are based on the commitment of individuals or student initiatives. To an increasing extent, also management boards of organizations now assume responsibility towards society and environment. While safety-related issues, such as the handling of hazardous materials, were of primary importance in the past, reduced consumption of energy and water, strategies to reduce waste production and environmentally compatible procurements are now gaining importance. Presently, 18 universities in Germany are certified according to EMAS or ISO 14001 [3]. To account for current developments, indirect environmental aspects are checked as well and the above three dimensions of sustainability are increasingly considered to be of equal importance [4].

In contrast to private companies, education and research institutions do not have traditional hierarchical structures and a clearly defined corporate identity. Education and research institutions are heterarchical organizations or loosely coupled systems of high complexity. Here, various status groups, professional and expert cultures, and organizational patterns exist in parallel [5]. To illustrate efforts to enhance sustainability, sustainability reports are published. These reports contribute to developing values that are reflected by the organization policy. Implementation of sustainability objectives is an indicator of management performance and illustrates the relevance of this issue, such that people are motivated to participate [6]. Starting point of reporting is an evaluation of the current status of sustainability performance. Quality of this evaluation depends on the availability and quality of data relating to economic, ecological, and social organization management and on the selection of appropriate key figures. Obstacles in sustainability reporting and evaluation are potential target conflicts and administrative weaknesses, but also the large expenditure required for data acquisition and the lack of valid information [7]. In literature it is often pointed out that data relating to real estate in particular are lacking [7, 8, 9]. In 2014, the EU Directive on Disclosure of Non-financial Information became effective for European companies of public interest (such as banks, insurance and investment companies), according to which these companies are obliged to publish their CSR activities. Aids to represent this information are given by international, European, and national guidelines, such as UN Global Compact, OECD guidelines for multinational enterprises, or ISO standard 26000 [10]. As of this year, large companies are also obliged to make energy audits according to the 2012/27/EU Energy Efficiency Directive (EED), if no energy management system according to DIN EN ISO 50001 or EMAS certification exists [11]. In the global business sector, reporting is based on the guidelines of the Global Reporting Initiative (GRI). These guidelines cover reporting principles and standard information as well as instructions for presenting ecological, societal, and economic performance data of the company and quantifying the impacts of business. Regulations for disclosing construction and real estate data are compiled in a separate chapter [12]. For universities, various approaches exist to assessing sustainable development. These approaches differ in the numbers and types of indicators analyzed, the weighing of these indicators, and the scopes of analysis (AISHE 2.0, STARS, AUA, GMID, STAUNCH) [4, 13]. Some education and research institutions adapt the GRI guidelines and add some individual indicators (e.g. Leuphana Universität Lüneburg, Forschungszentrum Jülich, Fraunhofer UMSICHT, Universität Graz). Examples of research projects embedded in the real estate management of education and research institutions are the projects Energy Lab 2.0 of Karlsruhe Institute of Technology (KIT) or the energy-efficient campus of the Technical University of Braunschweig [15, 16].

Real estate owned by research institutions and associations often are complex individual buildings accommodating experimental and administrative areas or buildings, in which administrative tasks are executed exclusively. The housing stock is generally characterized by a high heterogeneity and a variety of uses, building structures, and spatial distributions. Depending on the scientific discipline and profile, various purposes (laboratories, workshops, test halls, offices, and auditoriums) are combined. Real estate of universities and non-university research institutions are additionally characterized by several locations with building complexes and autonomous individual objects. Further, for the most part buildings are frequently embedded in a campus structure where all facilities needed are located on a confined area (facilities for education and research as well as for accommodation and infrastructure). Due to their design for specific uses, structural facilities are "special real estate", as certain types of uses, e.g. laboratory rooms, require a high degree of automation. The associated technical equipment usually limits other uses of the properties. Constantly changing learning and working worlds require constantly changing installations and equipment [9, 8].

The Düsseldorfer Erklärung zum Hochschulbau (Düsseldorf declaration relating to university construction, 2012) emphasizes the importance of buildings and technical infrastructures to the scientific performance and competitiveness of education and research institutions and the necessity of a lifecycle-oriented integrated management concept. Efficient organization and failure-free operation are prerequisites for ensuring scientific work and, hence, innovation and progress [14]. Apart from funds and staff, areas and their technical infrastructure facilities represent strategic resources of education and research institutions, which decisively influence the future development of the real estate. Contrary to private companies, real estate of education and research institutions are not subject to any sustainability management standards and codes. Experience gained from previous sustainability efforts as well as lacking regulations and holistic approaches give rise to the question of how self-obligations and commitments of organizations can be translated into real transformation processes.

2. Solution Approach and Methodology

Under the "LeNa – Leitfaden für das Nachhaltigkeitsmanagement in außeruniversitären Forschungseinrichtungen" (guidelines for sustainability management in non-university research institutions) project, leading research organizations in Germany cooperate to identify relevant fields of action for a sustainable development of education and research institutions according to the conceptions of the Brundtland commission. "Sustainable development" is understood to be an integrated approach and participative process, in which concrete sustainability goals are defined continuously and cooperatively in a context-specific manner. The project is divided into three partial projects focusing on "research and development of society", "staff", and "building and operation". This latter partial project analyzes the contribution of real estate management to sustainable development. The methodology used for this purpose includes an analysis of relevant expert literature, use of the institutes' own experience, private conversations, and expert interviews. In expert workshops with facility management representatives, the need for actions is studied, relevant fields of actions are identified, and topics and evaluation criteria of real estate management are discussed. Work is aimed at developing an integral systematic of single sections to support real estate management. Therefor through qualitative content analysis existing information material is condensed into core statements. The results are processed in the form of fact sheets, short reports, and case examples. For the approach to be holistic and to ensure transparency and comparability, principles have to be developed for the selection of reference parameters. The indicator sheet presented below is supposed to facilitate the use of key figures, such as energy consumption and emission, for sustainability reporting.

The term of "real estate" in this connection does not only refer to properties, but also to buildings and infrastructure facilities located on these properties. "Real estate management" accordingly covers all tasks of planning, building, using, and operating real estate. It is not real estate management that is to be sustainable. A sustainability-oriented real estate management rather is to support sustainable development with appropriate means and measures. Topics and aspects of sustainable development have to be adapted to the planning, building, using, and operating of buildings and the further development of building stocks, campus areas and infrastructure facilities and, thus, integrated into the existing real estate management system. Within the given organizational structures, universities and non-university research institutions are to be enabled to make long-term, lifecycle-oriented decisions for an efficient use of resources and for preserving values of real estate.

3. Results

3.1 Future-oriented Real Estate Management: Fields of Action

The fields of action in real estate management can be divided into certain strategic and operative areas and interlinking cross-cutting issues, handled in cooperation with representatives from organizational management and facility management (see Fig. 1). It is assumed that all activities in the fields of action through the management-cycle-analysis, for instance goal setting, formulation and evaluation of possible strategies, selection of appropriate solutions, implementation and performance review, are continuously improve a sustainable, more over a future-oriented real estate management and campus development.

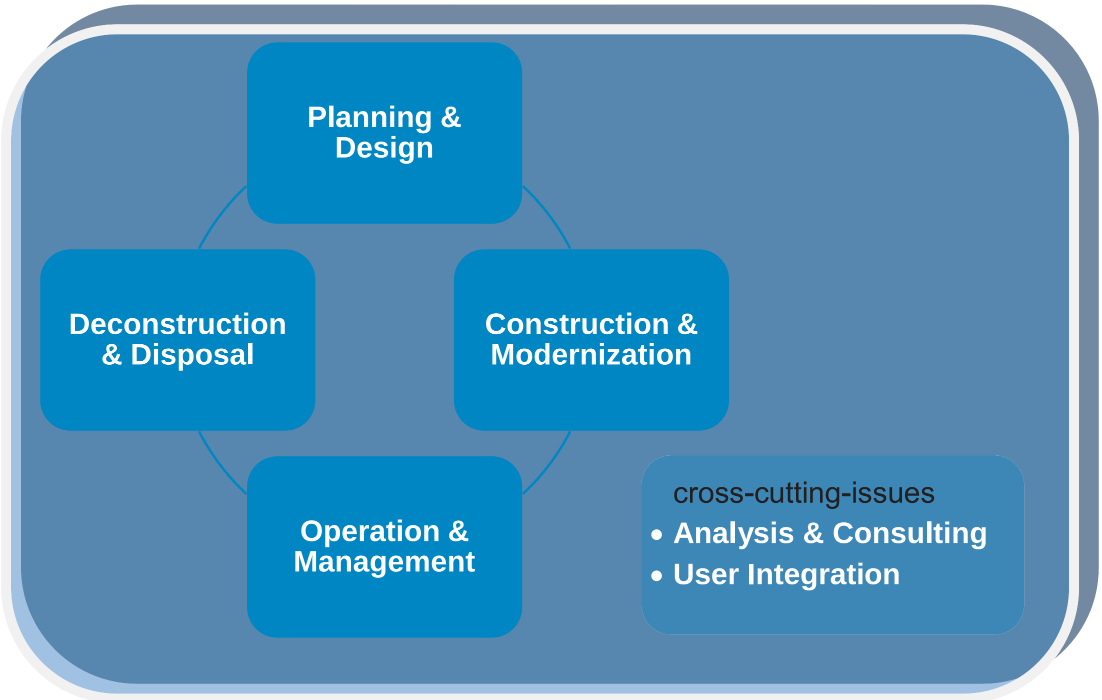

Figure 1: Regarded fields of action

Real estate management is a service rendered. It is based on an existing structure and development plan and supports education and research institutions in identifying needs for usable areas and technical infrastructure facilities in the short, medium, and long terms and in describing requirements to cope with the expected change of working environments and technological innovations. It also advises and supports the organization in formulating realistic and verifiable goals for the further development of the area and building stock and works on reaching these goals. Real estate management participates in and implements the sustainability strategy of the organization in the area of real estate development and selected areas of operational ecology.

Future-oriented campus development decisively depends on current and future needs for rooms and areas by the facilities located there. These needs can be derived from work and research profiles or development plans of the facilities in cooperation with all actors involved. It is a major and primary task of real estate management to supply a need-tailored, appropriate, and future-proof work environment, i.e. usable areas and technical infrastructure facilities to ensure proper present and future operation of education and research facilities. Execution of this task is guided by assuming responsibility for the environment and society. Adequate consideration of sustainable development principles means observation and integration of ecological, economic, and social aspects besides securing functional and technical quality in all fields of action of real estate management. Sustainability-oriented real estate management requires consideration of the following aspects at least:

- Functional and technical quality of areas, rooms, and infrastructure facilities for failure-free operation and value preservation of buildings;
- economic efficiency with an economical and reasonable use of existing funds;
- protection of resources for preserving the natural bases of life;
- environmental compatibility for the protection of ecosystems;
- health compatibility and comfort for user satisfaction;
- supply security for maintaining the operability of the organization;
- industrial safety for the protection of the integrity of users;
- design and urban planning quality for esthetic reasons.

To adequately consider current developments in the setting, persons responsible for real estate management take into account current trends and innovations as well as technical progress when deciding on the management, optimization, and further development of existing areas, rooms, and infrastructural facilities. In real-world laboratories and experimental and demonstration projects, real estate managers cooperate with research groups.

3.2 Recommendations for Future-oriented Real Estate Management

The fields of action of real estate management are analyzed and user-friendly approaches to implementing sustainability-oriented activities are worked out by the authors in form of fact sheets, indicator sheets, and other aids, such as case examples or short studies. As you may see in Fig. 2, fact sheets are interlinked with short reports, aids and best practices on the one hand. On the other hand they provide an access to indicators for measuring the sustainability performance of organizations. This is also the connection to sustainability reporting. The other way around: With the consideration of those indicators it is possible to improve the real estate management for a more green or future-proof campus. The contents of fact sheets and indicator sheets are described beneath in Table 1 and 2.

The relationship between fact sheets and indicator sheets is illustrated in Fig. 2:

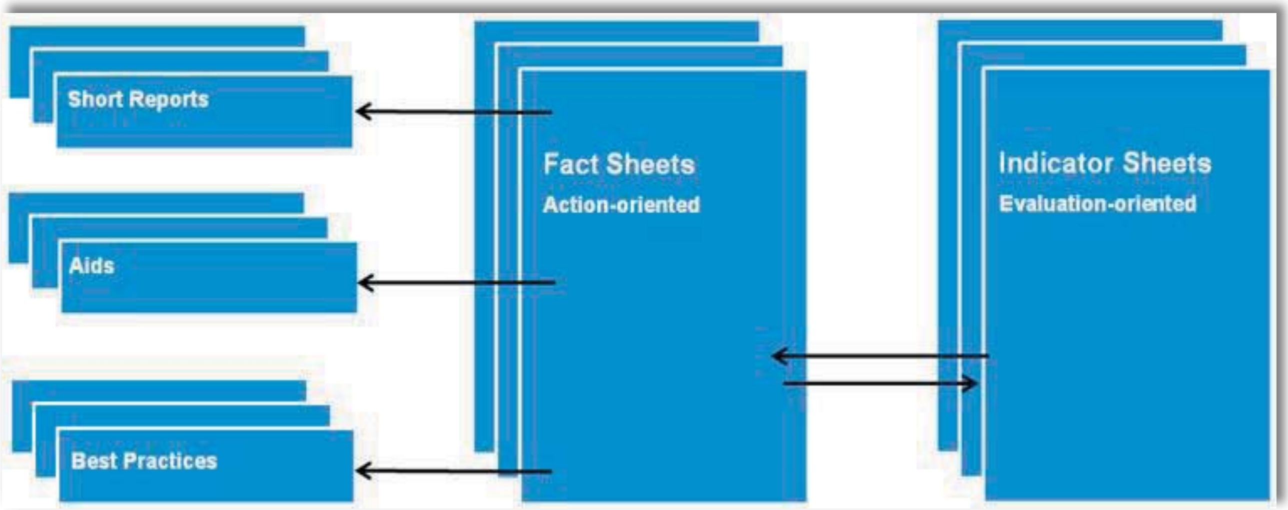

Figure 2: Relationship of implementation aids

Fact sheets are based on the structure and development plans of education and research institutions. It outlines the working steps that have to be executed for a proper real estate management.

Table 1: Contents of a fact sheet

Title	Content
Short description	General description of a field of action, definition of a topic
Responsibilities	Designation of the responsible actors (umbrella organization/ centers/institutes/divisions) and of the action level (normative/ strategic/operative)
Relevance	Significance of the topic to the economic, ecological, and social dimensions of sustainability
Normative guiding principles	Placing of the topic in the political/societal context
Legislative requirements	Relevant laws, regulations, and standards
Instructions for implementation	Description of implementation steps
Working aids	Methods and instruments recommended for implementation
Case examples	Examples of best practices

Topics that cannot be processed in the form of fact sheets are covered by short reports. These provide general instructions and place the topic in the context of sustainability-oriented real estate management.

According to the Bonn Declaration, achievement of goals has to be measured using appropriate indicators and effect-oriented reporting is needed [17]. The large number and selection of indicators to be considered in the sustainability management of real estate with limited personnel and time resources and limited system knowledge make it difficult to adapt the GRI approach to education and research institutions [7]. For this reason, action-oriented fact sheets are complemented by evaluation-oriented indicator sheets. They serve as a methodological basis to acquire, communicate, and assess data and as a link to sustainability reporting.

Table 2: Contents of an indicator sheet

Title	Content
Classification and goals	Characteristics in the operational context
Indicators	Main and additional indicators of process quality
Context	Reference to sustainability reporting, assumptions, and prerequisites
Description	Definition of the indicator
Data acquisition information	Indication of sources of information
System boundaries	Information on system properties
Measurement parameter	Subject of measurement
Reference parameter	Benchmark of measurement
Information on interpretation and analysis	Objectives, additional details

3.3 Comparability versus Non-comparability of Organizations

Key figures describing energy efficiency and ecological quality of organizations as one part of operational ecology have to be transparent and comparable. Coefficients of high aggregation level and reference parameters that have not been specified clearly are hardly suited for comparing entire organizations. When determining energy and emission coefficients, a use- and user-specific allocation of energy consumptions and calculated emissions should be made. Specific energy and emission key figures that relate an absolute amount of energy or emission to a parameter, such as an area; have to meet the following requirements at least:

- Appropriate measurement concept for use-related consumption measurement;
- differentiation of building types, types of uses, e.g. office or laboratory;
- exact description of the scope of balancing (e.g. heating, air conditioning, or stationary illumination);
- clear indication of the energy conversion level for energy coefficients (usable, final or primary energy);
- clear information on the origin and type of emission factor for emission coefficients (in case of climate gases, distinction between CO_2 and CO_2 equivalents);
- clear specification of the reference area (e.g. net floor area according to DIN 277).

In general, final energy coefficients are meaningful only, if they are given for every energy carrier. When key figures are to be indicated for the entire organization, conversion into primary energy as a measure of consumption of resources (renewable, non-renewable) or into emissions of climate-relevant gas as CO_2 equivalents is necessary. The primary energy factors (e.g. according to DIN V 18599-1) or emission factors required for calculation may also be combined in an average primary energy factor or an average emission factor in order to represent the real estate-specific energy mix.

Table 3: Final energy coefficients for the heating of various types of buildings, Source: Excerpt from [18]

BWZ	Building Category	Reference Value	Average	Area Corr. Factor	Reference Value	Average
		kWh/($m^2 BGF_E$*a)		NGF_E/BGF_E	kWh/($m^2 NGF_E$*a)	
130000	Administration buildings	65	90	83%	78	108
200000	Buildings for scientific research and teaching	55	85	88%	63	97
		kWh/(m^2living space*a)				
620000	Student residences	90	140	84%	107	167

BGF = Gross floor area, NGF = Net floor area

By way of example, Table 3 lists location- and weather-corrected final energy coefficients for the heating of various types of buildings according to the Bauwerkszuordnungskatalog (BWZ) (building typology of the Conference of the Minister of Construction, Germany). The final energy coefficients include those final energy consumptions that are typically applied to supply heat for the respective types of use, i.e. without warm water supply for administrative buildings and with warm water supply for residential buildings. As a rule, the reference parameters are the heated gross or net floor areas according to DIN 277 (or depending on the type of use, the living space of e.g. residential buildings). Conversion factors for the types of areas reveal differences when interpreting energy key figures as a function of the chosen reference parameter alone. The reference and average values in Table 3 are very good (smaller) or average final energy coefficients for the heating of various types of buildings. When using final energy, primary energy or emission coefficients to describe the development of consumption and emission over time (e.g. annually) and additional information on the development of the reference areas (extension, decommissioning or other uses), development of staff, and change of use or occupation times at least is required for a correct interpretation. If, for instance, consumptions increase in successive years, this may be due to a rising number of staff or to larger areas at the same energy efficiency. When the same number of staff or the areas remain the same, increasing consumption may be due to efficiency losses or longer working times (or vice versa in case of decreasing consumption) [19].

4. Outlook

Standardization of assessment and reporting principles and the education and research institutions' motivation to report about sustainability would contribute to assuring quality. In this connection, specific benchmarking does not only reveal the trends of an organization over time, but also allows for a transparent comparison of users and uses. It appears to be reasonable to conceive a GRI sector supplement for education and research institutions only.

To increase acceptance of the measures to be implemented, the actors of all interest groups (students, management, administration, science, society, politics) have to participate actively in the integration of sustainable development principles and especially representatives of science are obliged to cooperate. On the international level, the International Sustainable Campus Network (ISCN) contributes to supplying starting points and orientation knowledge for a systemic implementation of sustainability processes. To overcome existing obstacles, sustainability networks have to be made capable of commanding majority backing, disseminating awareness, and establishing the appropriate structures, such that experience will not be used within the institution, but also in the society as a whole [20].

5. Conclusion

Commitment of the “grass roots movement” is increasingly complemented by sustainability activities on all organizational and action levels of education and research organizations. The voluntary self-commitments of organizations are noble goals, but application-related implementation approaches are still lacking. Integration of sustainable development principles into education and research institutions may be achieved by the establishment of appropriate internal organization structures, e.g. a campus development staff unit, support of innovative sustainable consumption and production processes, establishment of an environmental management system, execution of ecological or sustainability audits, or environmental and development-related reporting based on adequate criteria. Users and other actors in society are to be encouraged to participate in this process by suitable means of participation and communication. Based on the findings gained from a selected research project, possibilities of integrating principles of sustainable development into conventional real estate management, e.g. into the areas of planning, building, using, and operating buildings and facilities of education and research institutions, have been illustrated. Work processes of facility or building management are to be supported when using and operating or modernizing the buildings on the real estate. The goal is a systematic management, optimization, and further development of the building stock by systematic maintenance and continuous adjustment of needs and stock. A comparative assessment of sustainability development in and between organizations can only be made with the help of appropriate key figures and valid data. Sustainability reports do not only serve communication purposes, but also represent an assessment instrument and basis for decision-makers. Suitable indicators for sustainability assessment and reporting are given by the Global Reporting Initiative. These may be transferred partly to the real estate management of education and research institutions. As institutions of the private sector differ from those of the public sector in responsibility, intention, and motivation, however, transfer of criteria is limited. This problem might be solved by the supply of action-oriented aids in the form of fact sheets, short reports, and case examples, complemented by assessment-oriented indicator sheets.

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Impact of the Project Initialization Phase on the Achievement of Sustainable Quality in Building Projects in China

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Summary

Sustainability is sought for in building projects worldwide, with international certifications being deemed as premium labels, expressly in China. Yet, to achieve sustainable targets, these must be set from the earliest stage, for they affect the entire building lifecycle. A process management from the project initialization (Phase 0) seems necessary to secure these goals. Thus the Phase 0 activities and the impact of their conduction quality on the overall project outcomes are examined on theoretical and practical grounds. Based on the Reference Building Process Map, used as a process evaluation tool, a set of key initializing activities serving valuable objectives and process quality was compiled. The systematical analysis of three Chinese projects exposed deviations between the quality of these steps' execution, their added-value for the projects and the subjective evaluation by the project members of the overall outcomes. For succeeding in sustainable quality, a constructive programming phase appeared as critical. Lessons learned and best practices could also be derived. Subsequently, well-defined and communicated goals lead to smooth project progresses and high target achievements. Also, advantageous constellation of project participants and their homogenous understanding of the project targets may compensate for gaps in Phase 0.

Keywords: programming, case study, Reference Building Process Map (RBPM), sustainable certification, China

1. Introduction

Sustainability certification schemes for buildings may be considered handy tools for building quality evaluation. Well-established systems such as LEED or DGNB address the results of

design and construction with a broadly conceived catalogue of criteria. They may also serve as a design reference for sustainable buildings during the design process [1, 2]. Yet they cannot be considered as project management tools, with a clear definition of the main activities to be carried out in a specific chronological order [3-6]. It seems therefore inevitable to implement a consequent process management along with the sustainability evaluation.
Ideally, the process management starts before actual design phases [7] in the form of an additional planning phase – the so called “Programming Phase” or “Phase 0”. It consists of the definition of process goals, scope, conditions and resources.

There is much written in literature about the need for programming, especially in North American and European studies [8], which cover a broad range of publication types such as governmental legislations [9-12], official design guidelines [4, 13, 14], sustainability certification systems [3, 5, 15, 16] and personal statements and publications [7, 17-19] among others.
Whereas the conduction of a programming phase seems widely accepted in Western countries [17], the authors perceived deviations between this theoretical procedure and real design practices in various international sustainable building projects. As being involved in Chinese building projects, the authors conclude that such a defined project initiation method is hardly established in the People’s Republic of China.
In China, the focal country of this study, the implementation of a programming phase is statutory, commonly leading to an architectural design competition at project start. By investigating various representative large public building projects, Deng et al. [8] come to the conclusion that there are still “significant gaps between the best and real practices in programming large public buildings”. Misunderstandings, lack of communication and differences in planning practice methods prevent the breakthrough of the internationally recognized programming practices.

Based on three case studies, the aim of the present study is to investigate the impact of the initialization phase on the achievement of sustainable building quality in real projects in the Chinese building sector. The study also aims to identify crucial process steps of the Programming Phase and to clarify their potential towards broad adoption in practical projects.

2. Methodology

Quality shortages in programming can only be revealed when investigating the detailed composition of Phase 0’s contents with an appropriate process evaluation method. The impact assessment of a proper project initialization on the quality level reached for a project was therefore conducted using the Reference Building Process Map (RBPM), as introduced by Tan et al. [20]. This map presents a chronological ordering of process steps for managing the development of buildings to a defined quality. It includes data about the type, the format and the level of detail of the information which each stakeholder should provide, as well as when it should preferably be delivered. The map was put together within workshops with experts of different backgrounds to ensure it reflects the current best practices. It got constructed systematically based on legal documents, standards and practical knowledge. Within the study it provided an orientation and reference for a good practice according to the focused initialization phase.

In the first place, the individual process steps were reviewed against the literature to assess the pertinence of each step within the programming phase and ensure the availability of a complete set of activities for a best practice Phase 0. To do this, for practicality, the RBPM steps were summarized into a list of activities within a wide range of topics to building project management.

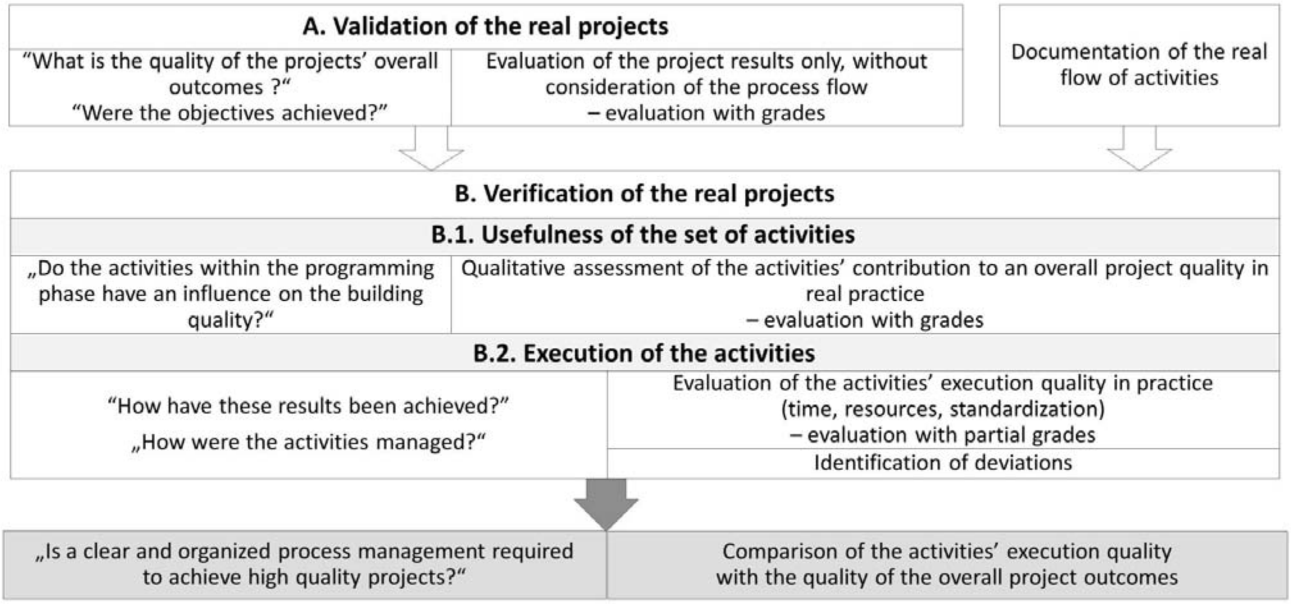

Fig. 1 Representation of the method followed to assess the benefit of a proper project initialization phase against the objectives achieved in three case studies

The following study then investigated real projects in China on their initialization process steps as depicted on Fig. 1. It consisted of comparing the Programming processes of the case studies with the Reference, thus identifying deviations that may lead to quality deficiencies, as well as analyzing the consequences of these processes throughout the projects.
For this second part, only a reduced number of topics were considered, given the type and amount of information accessible for each case study. Also, not all topics seemed relevant for the research focus on the sustainability aspect of high quality buildings.

First, a validation was done by answering the question: "were the objectives achieved in the real projects?" (part A in Fig. 1). To do so, evaluation criteria were defined to provide a common framework for all three case studies. Since a project may be considered as of high quality only if the overall project goals are met, the criteria chosen to reflect the quality level of the projects were based on the most decisive factors for building owners: e.g. achievement of the main project objectives (including specific sustainability goals), timely deliveries, etc. The criteria were defined in such a level of detail that they could be later compared to the results of the process evaluation.
The evaluation criteria ensured an objective assessment by any possible participant of the project. In this case, the evaluation was done by a sustainability consultant who took part in the three projects. Based on the criteria, he was asked to assess whether the project overall objectives were achieved by evaluating only the project results, without consideration of the process flow.

Second, the verification part aimed at evaluating whether the way followed was effective to reach the targets. The steps followed in each project in China were thus documented as they went, with more focus accorded to the early planning stages and especially the decision making activities. The documentation included at least the occurring time, the assigned responsible entities and participants, and the step's standardization level in reference to the team's usual way of doing.

Once documented, each real process step was qualitatively assessed on the value it brought to or took out of the overall project quality (part B1 in Fig. 1). Thus, it evaluated to which degree the conduction of the process steps within the programming phase had an influence on the quality of the building. It also related the process steps with their consequences in later phases.

The next question to be answered was: “how have these results been achieved?” This part (B2 in Fig. 1) focused on the detailed documentation on time, human resources and standardization level of the real processes. Each criterion was first qualitatively assessed and then given a partial grade evaluating the quality of each step. By doing this, deviations between the conduction and the added-value of each step were identified.

The investigation then focused on the activities with high discrepancies in the grades given. The following cases were considered with attention. (1) The activity was absent or executed with poor quality, but it has not caused negative impact on the overall objective achievement. (2) The activity was carried out at a high quality level but did not lead to a positive benefit throughout the project. (3) Additionally, when the execution and the overall project quality level highly differed.

By crossing the results of B1 and B2, lessons learned were derived out of cases (1) and (2) on ways to secure a better process quality for follow-up projects.

By running the validation and verification process on the case studies (parts A and B in Fig. 1), the real process steps got connected to the quality of the overall project outcomes. Since part B1 related the process steps to their consequences in the later phases, looking at these in a reverse order following the Reverse Process Design method [20] could highlight the link between the project overall difficulties with their original cause, happening in Phase 0.

All in all, the analysis has sought for providing practical proofs that a clear and organized process management was required to achieve high quality. Three further evaluations were derived.

a. A set of activities was identified for a proper project initialization phase with most positive effects on the objectives and process quality.
b. Real projects were assessed on their sustainable building quality. Process-wise, deviations were pointed out, where sustainable quality gaps were due to actual lack of process quality.
c. Lessons learned were derived on how deviations from the generic best practice initialization phase affect the overall objective achievement in building projects.

The cases serving the investigation of an intense project initialization phase were new-builts in China, all developed in close cooperation with Germany and using the DGNB scheme for sustainability certification.

Project A was developed by a private group of investors represented and led by a Chinese couple: an engineer and an architect. Both studied in Germany before setting up an architecture practice in Shanghai. In this special situation, the client and the architect, as well as the project developer were the same entity. This setup had strong influence on the quality of the design and planning process. Since the main project coordination and the investor were in one hand, a different project process evolved than in usual building projects in China. This project was more direct with less communication requirements and thereby also less obvious to the participants and observers.

Project B was developed as a pilot project in a Sino-German EcoPark development, initiated in high level political consultations. It was set to test and introduce a higher standard compared to the overall practice. The project team on the client’s side was highly motivated and demanding for quality, sustainability, economic performance as well as timely delivery. A special situation in this case was also that the later building tenant and operator had been involved in a strong position from the beginning. He demanded a high level of energy efficiency, functionality and comfort, based on his experience in a building similar to the one projected.

Project C was projected by a city government and developed with the political wish to build a representative show case for sustainable building in the city. The client has involved international sustainability consultants (with a representative name) at an early stage. However the project has been assigned to a general contractor without effective control implemented by the client. In the general contractor’s contract, a lump sum and a very general quality goal had been defined.

Table 1 Excerpt of the RBPM Programming Phase's process-steps with link to the literature

	Process-step	Reference in the literature
Objectives	Definition of overall project objectives	[3, 4, 7, 9, 11, 13-15, 17-19]
	Development of the Design Brief	[3, 4, 7, 9, 11, 13-15, 17-19]
	Clarification of main specifications and conditions with preliminary team	[4, 7, 9, 10, 13, 14, 17]
	Assignment clarification, project roles, responsibilities, task distribution	[3, 4, 7, 9, 11, 13-15, 17]
Time	Preparation of the time schedule	[7, 9-11, 13, 15, 17, 19]
Staff	Preparation of a staffing plan	[3, 9, 11, 13-15, 17]
	Decision for a specific project set-up	[9, 11, 13, 14, 17]
	Decision for the enrolment process, such as tender	[9, 11, 15, 17]
	Development of decision supports	[9, 10]
Sustainability	Decision to have sustainability certification and BIM project	[3, 4, 6, 9]
	Definition of certification-related objectives and requirements	[3, 4, 6, 9, 15]
	Selection of a specific certification program	*
	Enrollment of a sustainable certification expert	*
	Definition of the necessary analyses / studies	[3, 6]

* The two process-steps with regards to sustainability are not referred to in the literature. However, it is evident that if a sustainable certification is prepared, there is a need for selecting a specific program and enroll an expert for advising on how to achieve the program, although this is not mentioned in the literature, and especially in the certification scheme documents themselves.

3. Results

3.1 Assessment of the RBPM against the literature

The review against the literature of the RBPM's individual process steps is summarized in Table 1. It shows the four topics selected during the second part of the study, the corresponding process steps and the references found, describing the necessity of each respective process step.

3.2 Subjective analysis of the project outcomes

In order to get a first impression of the project achievements, a catalogue of questions related to the quality of the project outcomes along the lifecycle was used to assess the four topics sustainability, staff, time and objectives. The results are summarized in the first column of each project in Table 2.

The analysis results show different qualities of each of the three projects. Project B performs best, only small problems occur in the project schedule communication, the overall project vision definition, as well as the enrollment process for the project team. The same picture also applies to project A, with in average an overall weaker performance. Project C has a negative assessment of the project performance in many criteria addressed.
In projects A and B, the teams were aware of the current achievement level for the key sustainability targets, while the targets in project C were not present and transparent for most of the participants throughout the project. This resonates with the level of awareness as well as the clarity of the goal formulation and the communication of needs and targets. When the targets were present for the participants, their achievement has been followed over time (projects A and B), while, according to the respondent, the design process was not guided by a set of clearly formulated goals in project C.

Table 2 Summary of the evaluation grades for the three case-studies

Legend: Quality loss: ○, Moderate quality: ◒, High quality: ●

Topics	Activities		Project A: Project overall quality	Project A: P0 execution quality	Project A: P0 process step added-value	Project B: Project overall quality	Project B: P0 execution quality	Project B: P0 process step added-value	Project C: Project overall quality	Project C: P0 execution quality	Project C: P0 process step added-value
Objectives	Definition of overall project objectives		◒	●	◒	◒	●	●	○	◒	◒
	Design Brief		●	●	●	●	●	●	◒	●	○
	Clarification of main specifications and conditions with preliminary team		●	◒	◒	●	●	●	◒	◒	○
	Assignment clarification. Project roles, responsibilities and task distribution		◒	○	◒	◒	●	●	○	●	◒
Sustainability	Decision to have sustainability certification		●	●	●	●	●	●	○	●	◒
	Selection of a specific certification program:	DGNB	●	●	●	◒	◒	◒	○	◒	◒
		GBL		●	◒		-	-		●	◒
	Enrolment of a sustainable certification expert:	DGNB	●	●	◒	●	◒	◒	○	●	◒
		GBL		●	◒		-	-		○	●
	Definition of certification-related objectives and requirements:	DGNB	●	●	●	●	●	●	○	○	●
		GBL		●	◒		-	-		●	◒
	Definition of the analyses / studies necessary		●	●	●	●	●	●	○	●	◒
Time	Time schedule		○	●	●	◒	◒	◒	○	◒	○
Staff	Staffing plan		●	○	○	●	●	●	◒	○	○
	Decision for a specific project set-up		◒	◒	●	●	●	●	○	○	○
	Decision for the enrolment process, such as tender		◒	●	●	◒	●	●	○	○	○
	Development of decision supports for enrolment process		◒	●	◒	◒	●	●	○	●	○

Besides the overall goal definition, the application of a building certification system was addressed in the question catalogue. While the certification schemes played a role in all projects, the choice of the scheme, its implementation degree, criteria understanding, as well as the influence of the sustainability consultant largely differed. While projects A and B decided for a specific system and its complete implementation, project C hesitated to take up a formal set of project requirements defined by the scheme. The projects also differed timewise for the certification system selection. In case B, some pre-assessments and feasibility studies were conducted before the decision to use the DGNB system whereas the system was adopted without prior deeper analysis in case A.
The resulting application of the certification system was slightly different in projects A and B. Project A followed an overall holistic approach and the measures were designed to some degree, but not fully defined. Project B was less committed to a high performance in all criteria but required that all qualities were carefully developed and reasoned. In comparison, project C followed a quite different procedure of using the sustainability certification system more as a reference then as a design scheme. The option of getting certified thereby was kept open until a very late planning status, but no commitment to the achievement of certification goals was made.

3.3 Analysis of the activity flow

The second part of the case study analysis investigated to which degree each process step provided added-value to the overall project and whether it was well conducted. The analysis was

built to track down the planning activities being carried out well without adding value, as well as those which were not carried out well.
Table 2 summarizes the result of the analysis: the second column of each case study indicates the quality of the process step execution and the third column indicates the added-value of the process step for the overall project. For evaluating the deviations in the grades, the identified planning errors are listed, sorted by topic and project.
Although several process steps have shown such a discrepancy between conduction and added value (e.g. the definition of the design brief or of the time schedule in project C), providing the scope of this article, the investigated process steps focused more on the sustainability certification aspect than on the other topics included in the programming phase.
It is thereby to be differentiated between the local standard Green Building Label (GBL) and the international sustainability approach, represented by the German DGNB label.

3.3.1 Failing to perform in accordance with the certification scheme

Although it seems like most considerations of sustainability certification systems have been beneficial to the programming phase, the respective activities were not always conducted well. Especially for project C, the definition of certification-related objectives and requirements was not carried out in accordance with the DGNB certification scheme. This activity’s poor grading comes from the uncertainties within the decision-making process for the questions “how high to classify the importance of sustainability?” and “how to take and implement sustainability consultation?”
Depicted in the overall qualitative assessment, the missed chance for an early decision of a sustainability scheme led to some confusion in follow-up activities.

3.3.2 Aiming at the Green Building Label

For all projects it seemed to be a common practice to follow the Chinese sustainability certification procedure. Questions about the conduction of each activity (who, when and according to which standard procedure) could be answered easily, which gives credit to the familiarity of the process.
Yet, focusing on projects A and C, it was observed that aiming at a high standard of the Chinese GBL label did not affect the design process much or on a holistic basis. The GBL implementation seemed more like an additional feature a building can be equipped with rather than a tool interfering with design and process decisions. Also, the decision for the GBL implementation did not always come from a firm advocacy for building sustainably but it was rather a required supplement for doing land acquisition.
The reference set of activities defined are aiming at an early influence of the sustainability certification system on the design (selection of a specific certification program, enrolment of a certification expert, definition of certification-related objectives and requirements). Yet, the implementation of the Green Building Label seems to follow different rules.

3.3.3 Aiming at the DGNB

Focusing on the implementation of an international certification system, such as the DGNB System, it is obvious that such an international scheme is not aligned to the Chinese standard building process. When looking at the “definition of certification-related objectives and requirements” in project C, a major deviation appears between the conduction and the added value grades of this activity.
While investigating with the questions to the set of activities, it appeared that even though conducted impeccably, activities could not show added value to the programming phase. In

deeper analysis, by questioning how, when and according to which standard procedure the activity was run, it became clear that the activities were carried out more like a parallel process than like a design-affecting consultancy, which contradicts with the scope of doing programming.

4. Discussion

As assessed against the literature, the Reference Building Process Map (RBPM) includes the main steps needed to achieve sustainable building quality. It can serve as a guide for later projects. Additionally, the RBPM could be used as a method to do research on the state of programming of sustainable building projects in China and to question the international approach (RBPM) by comparing it with actual building practice in China.

In real practice, most cases have shown that running the set of activities identified for the initialization phase has provided added-value to these steps and a good start for the project, thus subsequently leading to high quality project outcomes. The set should however be slightly adapted to each project to specifically match its goals. Yet, with the case studies, it could already be enhanced with best practices and lessons learned for further applications in projects with similar setups e.g. as a support to predict the effects of executing the steps with low quality.

As further main outcomes, the case studies have shown that sustainable quality can only be achieved when the project objectives are clearly defined. Both a qualitative and a quantitative definition must be provided by setting respectively key sustainability targets and the level of achievement aimed. These must then be validated by the building owner and accepted by the design team. Communication is indeed crucial to increase the common understanding of the sustainability criteria and the influence of the scheme on the overall project outcomes.
In this study's specific context, communication difficulties were highlighted by comparing the processes related to the local versus the international certification scheme. It was seen that getting the GBL for the projects in China has generated less difficulties in practice than the international certification system. This ease can be interpreted in two ways.
On the one side, it is generally understandable that the use of a new and unknown system comes with more effort. It can thus be assumed that this difficulty would also arise in other countries when trying to get a foreign certification. Getting sustainability consultancy is highly suggested to ease the scheme understanding and implementation with a well-defined action plan. The correct execution of this activity is therefore crucial as it directly relates to other activities and thus influences the benefits of the scheme for the overall project outcomes.
Moreover, it was observed that for the implementation of the international sustainability scheme's targets and measures, a direct mandate is most necessary in order to have an action plan approved and dictated to all participants of the design phase. Besides that, it could be clearly stated that a proper set and description of requirements, expectations and project roles is essential for a successful building project. The later the requirements are implemented into and specified within the process, the more potential problems occur. Project B showed that a high commitment to the overall target and a good communication within all participants could compensate lacks in process quality.
On the other side, the GBL does not influence the design in the early stages like the DGNB system, but only from the detailed design stage. To make sure that the work done until this later stage can be fully exploited, it is essential to follow a structured management from the beginning. Especially, follow-up for the Phase 0 activities is required in the later stages to diminish the risk of not reaching the goals and to get the maximum added-value for the activities already performed.

In this study, the need for programming could only be evaluated on short-term effects, since the projects studied were not completed yet. Since the RBPM depicts more than the programming phase, further case studies should be carried out to evaluate the impact of the activities in the later stages as well as the long-term consequences of programming on the overall project outcomes. Further research is also required to assess the impact of other topics on the building quality. In the present study, only a few topics were analyzed and discussed deeply. Other topics not addressed here (e.g. costs issues) would also be relevant for the overall project quality.

The present results may not be directly transferable to other building approaches in other countries. It can be said, that the evaluated projects all were a very specific project setup. All projects originated from Sino-German cooperations, all being willing to get to know the German sustainability certification approach. Other project setups might not show the openness and flexibility that a project must have in order to adapt to new standards. On the other hand, it is trusted that following a structured framework in projects involving a local team only can increase the sustainable quality, even when aiming for international certifications without foreign support.

5. Conclusion

The study has shown that the initialization phase is critical for the achievement of sustainable building quality. Having a clear structured process management like the RBPM can secure the project overall outcomes. It can provide guidance for the way building certification systems are used from the project start. Among others, setting and communicating clear goals to the design team appeared as a key process for securing the sustainability quality.
The case studies have highlighted that, although the stakeholders were aware of the importance of this process, specific support for formulating the targets is lacking. There is also a need to follow-up the results produced at each stage in order to get most value of it. In this sense, a framework for monitoring the project quality is also missing.

To solve these issues, two methods are suggested, which should be examined in further studies.
First, defining specific and measurable targets for the building in an early project phase may be a difficult task for building owners without technical background. In this sense, the use of the “Corridor Approach” may be a solution. It is characterized by starting with very general and overall objective identification by the building owner. Reflecting and correlating these objectives with well-known reference examples for each technical requirement provides landmarks to better understand these and to define an objective corridor for each target. The extremities of the target corridor are defined relatively to the quality level of the references. This method has several benefits: it leads to a clear first description of the overall expected objectives and it already provides the building owner with a corridor reflecting his expectations. The method can further be correlated e.g. with a design competition. On the one hand, the design teams are requested to provide an answer according to the formulated objectives. On the other hand, the method enables the exact positioning of the specific design within the target corridor. This allows an easy assessment and a direct ranking of the designs based on their diverse quality levels. It gives as well feedback about the feasibility of the expected targets. For the following phases, the owner is then able to reduce the target corridor, if not deciding directly on a specific target value. This method, developed during project C but not applied in practice, should be further investigated.
Also, the use of the Validation and Verification method [21] could assure that the project outcomes get closer to the requirements. As a quality framework to be used during the project run, it validates each partial result obtained against the target, while constantly verifying whether the

method followed is appropriate to achieve the target under the defined requirements. This method has already been used in the construction, yet its relevance for Chinese projects remains to study.

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Implementation of Sustainability Success Factors in Processes of Portfolio Management

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Summary

Managers of German real estate portfolios are increasingly faced with sustainability matters due to a growing public awareness of this topic. Requirements come from nearly all stakeholder sides. Especially portfolio investors, tenants and public sector ask for clear sustainability strategies in order to fulfil their own sustainability requirements. Based on the portfolio strategy and its planed holding period of a building in the investment fund, portfolio management processes are linked to the lifecycle during this holding period. This paper shows how sustainability related factors play an essential role in nearly all processes and can influence the success of the management. Overall, a functional real estate risk management should exist that recognizes sustainability related factors and implements them in the continuous risk assessment. The paper shows how these factors are already implemented and are discussed in terms of their further implementation in the mentioned processes. Lower operating cost, better rentability and higher rent increase are only some of the advantages of a sustainable building. Therefore, one core element of a sustainable portfolio management strategy should be the focus on sustainable buildings during acquisition and the improvement of their sustainability during holding period. This paper shows an example of how sustainability related factors are already implemented in portfolio management strategies and how such strategies can be further improved.

Keywords: portfolio strategy, portfolio management processes, real estate risk management, sustainability related factors

1. Introduction

Sustainable products reduce the risk for suppliers, consumers, the environment and society. They also pay off in another way, by creating opportunities for long-term growth and capital appreciation. The existing triad of risk, return and liquidity is increasingly being combined with the triad of ethical, environmental and social standards. This is particularly the case for investors in open-ended real estate funds.

The sustainability characteristics of real estate portfolios are therefore becoming increasingly more important for investors. Many commercial tenants consider rental property certification a necessary condition for concluding a lease agreement. Occupying an appropriately certified property also helps companies achieve their own sustainability goals. Sustainability characteristics are increasingly joining other criteria – such as location and the "war for talents" – in determining the long-term competitiveness of individual properties and are therefore becoming more economically relevant. This must be appropriately reflected in fund and property strategies.

The growing importance of the consideration of sustainability for institutional real estate investors is visible due to the increasing public debate and the rising number of scientific works on the topic. The subject itself is discussed for decades in science and practice and should be therefore in a modern real estate portfolio management approach also adequate considered. With regard to the conceptual design and the inclusion of sustainability in existing processes exists in institutional real estate investors no uniform approach. A uniform standard to what extent the processes of modern real estate portfolio management on sustainability aspects can be align is not identifiable at the present point of time. Last but not least against the background of increasing climate problems in connection with the high energy requirements of buildings the scope of this subject can be derived. The environmental component is but only a part in addition to existing economic and social aspects of sustainability. [1]

An analysis of the existing international standards and their implication on the real estate portfolio management are necessary for assessing the importance of sustainability for the management of real estate portfolios, in addition to the basic definition of the concept of sustainability. To do this, legislative as well as private-sector measures exist both at national and at international level.

To emphasize are the elements of the social responsible investing (SRI) and corporate social responsibility (CSR) and at the international level by the United Nations of adopted principles for responsible investment (PRI). The PRI include six principles for a responsible asset management, now signed by more than 900 institutional investors. At national level, in particular the Association initiatives of the Zentraler Immobilienausschuss (ZIA), as well as of the Bundesverband Deutscher Investment-Gesellschaften (BVI) are organizations that discuss sustainable topics with their member companies and try to develop sustainability standards for investors and other real estate companies. The sustainability code developed by the ZIA includes a clustering with the respectively applicable principles tailored to the respective real estate company sustained action. Additional exists an extension of the code to the theme of Green leases. [2] The guidelines of the BVI to sustainable investing make reference to particular national as existing international standards (including the aforementioned).[3] In addition reporting requirements exist from initiative (GRI) with the addition for companies in the real estate industry (CRESS), which is reflected also in the sustainability code of ZIA reporting on sustainable reporting by companies such as the global.

Beyond these basic standards various methods and systems for the measurement of sustainability exist. In this regard, especially the regional department members of the World Green Building Council which are Deutsche Gesellschaft für Nachhaltiges Bauen, U.S. Green Building Council and Building Research Establishment can be named, that offer the country-specific certification systems, BREEAM, DGNB and LEED.

Starting from the existing sustainability standards at national and international level a corporate sustainability strategy is necessary that integrates sustainable factors to investment and disinvestment decisions, which has ongoing real estate management influences as well as to all other relevant processes for their integration in real estate-related processes first on the basis of sustainability aspects.

Institutional real estate investors have usually extensive investment strategies with regard to the nature of the target objects to target building types, quality and building quality, types of use, location characteristics etc.. To what extent these sustainability aspects play a role for this decision processes should be examined and analyzed in this paper.

In a first step the basic process of portfolio management will be investigated for a holistic approach to the sustainable management of institutional real estate investors. Therefore the in the major process of portfolio management involved units and are assessed with regard to their entry in the value creation process. Central control unit is the actual portfolio management which controls the process units, shall adopt guidelines with regard to the targets as well as makes the ultimate decision. [6]

There is also the role of technical units for analyzing the nature of the building, to analyze the asset management to assess the economic parameters, as well as the actual transaction performing unit. To avoid serious risks of litigation an integrative approach to risk management should be pointed out, in conjunction with the above units and identified the main risks generated continuous solutions for their minimization. In this work should be shown that this approach includes already economic sustainability aspects, but can be also extended to other sustainability criteria.

In addition, the flow of information with regard to the assessment of the essential technical and economic parameters plays an important role in the real estate purchase process. A close coordination of the relevant units responsible for their assessment, as well as the interaction with external partners in the context of due diligence, is this a decisive success factor for a successful real estate transaction processes in practice.

Another important component in the process of buying represents the structuring of the transaction in which the optimal form of holding of investments, the optimal level of funding as well as more substantial fiscal and financial aspects are determined. Sustainability is reflected in particular in a structure, which will generate sustainable returns for the total portfolio, which minimizes the risk of loss changes of economic and legal framework parameters due to your flexibility and adaptability. Appropriate profitability calculations take into account in addition to the Basic object specific parameters (market value, current Cash Flow components, expected sale price, etc.), imply end of risk parameters, as well as structuring relevant components.

2. Methodology

Requirements for the integration of sustainability aspects per consideration level

Before closer is entered on the individual basic models of modern real estate portfolio management, is first of all to clarify, what basic conditions must be created for the ability to integrate sustainability aspects in the company by commercial real estate investors to these issues later in the individual models to incorporate can. To do this, it is advisable to analyze the consideration levels in detail and to examine your interaction with each other.
Larger companies of commercial real estate investors are facing in practice often the challenge provided, but are very much data that can be used for the measurement of sustainability, but a systematic treatment of this data and its integration capacity is not known. On the other hand, substantial data but again lack critical key locations.

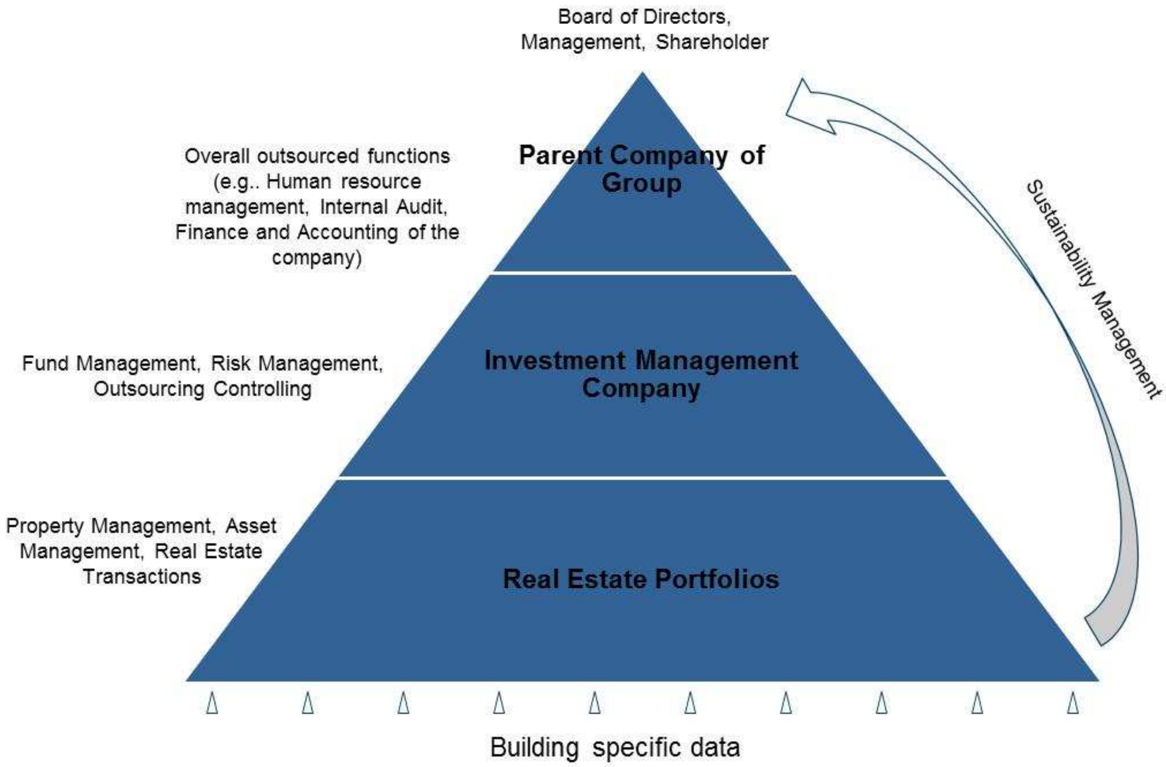
Here, the first two prerequisites are already clear to the integration of sustainability aspects in modern real estate portfolio decisions. The required data must be known, you must be prepared systematically and in case of missing data appropriate measurement procedures or other data collection methods must be found to these data to obtain.

The key performance indicator (KPI) is a term mentioned often in this context. Depending on the intention of use different KPI´s play an essential role and accordingly be applied. Currently measurable performance data of each property are for instance used for real estate valuation purposes, whereas for rating evaluation qualitative factors affecting the stock holder itself are involved into consideration. [7]

Key performance indicators are measures that represent a specific level of performance. These are applicable to all running processes of a real estate portfolio management company. Deviations from specific targets can be identified with these indicators. [8] They are also applicable to real estate specific processes. Possible indicators are for instance primary energy consumption or CO_2 emissions.

Green Building Certification Systems are also based on indicator based data collection bows where sustainability indicators are evaluated and transferred into the overall certificate of the building.

An essential role play also the viewing levels in the company, the recipients of the evaluations and the intention of what wants to be achieved with the individual evaluations.



Picture 1: Own Drawing following to Mösle, 2013, page 9, „Leitfaden zur Nachhaltigkeits-messung in Immobilienportfolien, Betrachtungsebenen des Nachhaltigkeitsmanagement“

Returning to the levels of consideration in the company the starting point as described in the previous section is set out the individual real estate itself. It is possible go even one step further on individual plants, building parts or elements of the construct of the building broken down. At this point for simplification reasons these fact is waived. The majority of the data required for the measurement of sustainability is nourished by this level of consideration. The essential features and performance data such as:

- Consumption costs (e.g. energy)
- Spaces
- Building Conditions (e.g. lack of maintenance)
- Prices (e.g. price of the property itself)

can be generated out of this level of consideration. Furthermore qualitative factors such as type of leases (keyword green leases) can be included into consideration.

One level higher is the portfolio level. A portfolio is a bundle of several Asset Investments. [5] In the case of modern real estate portfolios, these investments therefore consist of various objects of real estate buildings and land, supplemented in the case of real estate funds after german investment law (Kapitalanlagegesetzbuch) through liquidity facilities and other facilities of minor importance.

At the portfolio level a compaction and summary of the data collected at the building level is categorizations enriched to the portfolio specific categories. While it is self-evident, that the data collected at the building level must be homogeneous, i.e. the data must be available equally for all the buildings in the portfolio and be evaluated. In reality it is often facing the challenge that modern real estate portfolios often spread over several countries with different legal frameworks, measurement units and building specifications. In addition, that certain consumption data, such as for example the power consumption is often only the individual tenants available. Missing legal obligations to disclose and lacking provisions in lease contracts are factors that complicate this additional. The recording of consumption data can therefore represent a lengthy process in which tenants for the benefits of the resulting generated benefits must be made aware and convinced. The aforementioned Green leases consider these facts for instance.

These examples show that both levels of contemplation (building and portfolio level) are closely related and the implementation of sustainability criteria in decision-making processes of the portfolio management can be achieved only through the implementation of new tasks and processes in both planes. To achieve this goal an enhanced object support from the portfolio manager as well as a more complex portfolio management system are essential. The real added value of the approach discussed in the previous is the comparability of different buildings or at one level higher the comparison of portfolios within the framework of benchmark and time series and analyze them in terms of potential for improvement. In the case of the comparison of several portfolios the level of consideration can be set at company level. At this level, more global cross-cutting factors are added next to the aggregated portfolio data.

Real estate investment fund management companies are often part of a group as a whole with other business segments, which are detached from the pure real estate portfolio management (e.g. stock fund business, pension fund business, etc.). The investment companies based in the individual business segments have usually outsourced to the group companies central tasks. Central areas are for example:

- Services of the corporate internal audit
- Compliance
- legal financial accounting of the capital management companies
- human resource services
- services to information technology (central data server, care and maintenance of applica tion systems, etc.)
- and others

It is important that the respective investment company keeps a comprehensive controlling of outsourcing, which ensures that these outsourced activities meet the same standards as if these services would be provided directly by the respective investment company. This is also governed by section 36 of the investment code (Kapitalanlagegesetzbuch).

Which role play sustainability aspects in this context? Unless the respective management company has subjected to for specific sustainability objectives, codes and other obligations, commitments or similar, it is certainly by itself, that these requirements for the above-mentioned activities should be covered. Due to the fact that these areas are usually further away from the actual real estate business, apply at this point especially more global, company-wide sustainability goals. In particular, this can be the part of aspects of sustainable human resources management, community involvement, sustainable banking products and sustainable communication on group level. Here are above all the interfaces, as well as the networking between the viewing levels of importance. The sustainability management at portfolio or investment company level must communicate to the overarching sustainability management at group level to ensure that the appropriate messages to external stakeholders (investors, investors, public authorities, shareholders, etc.) are communicated and take appropriate account of the corresponding real estate specific messages.

The already mentioned outsourcing controlling can serve as a second supervisory body to review the implementation of the goals and requirements.

Coming back to the evaluation in the form of benchmark and time series analysis, more essential basic conditions are necessary, so that it is at all possible. In the case of time series analysis reliable time series must be a prerequisite, which show the development of the previously defined indicators. What sounds of course in practice but often when put on a new sustainability management faces the challenge that data are available only from the setting up of the newly created entry cycle and historically part cannot be generated. It is important therefore mainly that a regular cycle is created with as direct as possible data collection. If direct data collection on the basis of specific requirements is not possible derivation from other sources must be used as an alternative solution. Costs settlements are an example, if the direct measurement of the data is not possible.

Sustainability is a process which concerns all stages of value added

The notion of sustainability is now an integral part and cause of many discussions in the real estate industry worldwide. This, in addition to providers of real estate-related products and construction services providers, including associations, science and politics are involved. Nevertheless, the process of defining sustainability how it can be measured and on which areas it can be applied is still not finished. In many cases sustainability is considered real estate focused on the individual building rather than a process that affects all stages of value added and thus helps to ensure the economic performance of providers in the long term. Key point of discussion is the question of the efficiency of measures to enhance the sustainability, because often only insufficient "safe" yields can be generated in comparison to the generally well discoverable costs.

While property owners, who can invest their own money, not sufficient economy against the background of their own values positively decide nevertheless appropriate measures, this is (in the following referred to as "KVG") for owners such as capital management companies, the trust funds not so easily defensible to manage.

Generally, investors in a real estate fund grant the trustee only an economic mandate without an additional socio-political mandate. The management company therefore must give top priority exercising their fiduciary mandate, as companies and trustees for investors in the long term to offer an adequate running yield from regular earned income from real estate and cash, as well as a possible continuous growth, due to growing heterogeneity of values and socio-political desires of investors. Nevertheless assumes the management company with the assumption of trust funds also the concomitant responsibility for society, the environment and employees, and has to meet this. Based on this conviction some companies have anchored the principles of a business alignment sustainable in economic, ecological and social terms in your target image. [4]

As is shown in the following sustainability thereby plays a central role at the levels of production, product and producer.

Production-level - the product of the interaction of sustainable real estate and risk management

Sustainable Products

Sustainable products reduce risks for providers, the environment and society. At the same time, they open up opportunities for long-term growth and value creation — and pay off this twice. Increasingly, social, ethical and ecological standards form an inclusive triangle to the existing rate of return, risk and liquidity. Within sustainable production the real estate / portfolio management as well as the risk management are of central importance.

Sustainable Real Estate Management

For investors and tenants, therefore also increasingly sustainable aspects of the real estate portfolio play a role as well as profitability, security and flexibility. For many commercial tenants, the certification of the rented property is condition for the conclusion of a contract, because the costs as for energy consumption are generally less expensive and in addition their own sustainability requirements of businesses renting to are met. Sustainability aspects determine the longer-term competitiveness of individual real estate here in addition to other criteria - such as for example the location - increasingly and are thus economically relevant. This is appropriately taken into account in the Fund or real estate strategy. Therefore many real estate management companies aspire to the certification of their objects by the Green Building Certification Institute GBCI and other recognized providers, as some of the German society for sustainable building (DGNB), leadership in energy and environmental design (LEED) and building research establishment environmental assessment method (BREEAM). Certified are buildings that are energy efficient and thus environmentally friendly and health fair planned, built and operated. Such as water efficiency, materials used, and the air quality in the building are relevant for the certification. So not only ecological and social requirements, but also the life cycle cost for the owner reduces. Supporting acts the priority purchase of certified or certifiable real estate, where you then initiate the measures necessary for the certification within reasonable time itself. During renovating phase apart from the various certificates an energetic adaptation of the energy concept should be recognized. One additional aim could be the continuous expansion of "Green lease and administrator agreements" in which tenants and service providers undertake by appropriate clauses to ensure sustainable use and reduction of costs through intelligent management of real estate. In some countries of investment, this is definitely already experienced practice, in others there are still an awareness of the subject and an anchoring in the treaties. Real Estate Managers often cannot insist on 'green' leases in today's tenant markets because otherwise threatening temporary empty stand risk is incompatible to the trust promise to their investors. Energy-efficient and environmentally-friendly buildings benefit thus the environment, tenants and accordingly the investors in the form of a safer long-term return through the increased impairment. These aspects are appreciated also by the corresponding rating agencies when assessing product quality.

Sustainable Risk Management

In addition to the real estate portfolio, another essential factor for sustainable products is an appropriately aligned and integrated risk management to ensure the sustainable carrying capacity of risks. Therefore, real estate funds invest according to the principle of risk spreading. For the selection of properties for the Fund its sustainable profitability as well as the scattering according to location, size and use is a major point that has to be recognized. The real estate portfolio is optimized by fund management according to the requirements of the market and market developments by building modernization, restructuring and purchase / sale. Decision making is supported by the results from risk simulation of the following risk types:

- **Counterparty Default Risk**

Real Estate Funds achieve ordinary income from collected and used not to cover expenses rents from real estate, from investments in real estate companies, as well as interest and dividends from liquidity facilities. To measure the potential impact of tenant risks and case-related control, in particular credit analysis for a large part of business partners have to be carried out regularly. In addition, special transactions, such as purchases or large rental, undergo particularly performance-relevant business partners of an additional individual assessment. Bulk risks are taken into account on the basis of the detection and measurement of industry clusters or top tenants to limit about the proportion of tenants total rent of the Fund.

- **Price and Interest Rate Risk**
  Price and interest rate risk from the liquidity facility can affect performance. Typically, the liquidity facilities as a short-term investment be made and held-to-maturity. These two factors limit price and interest rate risk.

- **Exchange Rate Risk**
  Real estate funds invest in currencies outside the euro zone, the value of which changes with the development of the exchange rate of the relevant currency. The real estate market value as well as the existing liquidity is hedged normally to almost 100% in most public funds in order to reduce risk for investors.

- **Market Price- / Real Estate Risk**
  Related to the purchase of shares of the funds the investors is involved in the price development of the real estates within the fund. Thus, there is the possibility of value decreases by a negative development of individual real estate, as well as the real estate markets as a whole. At the level of the individual properties may cause depending on the financing structure, for example up to a total loss. This risk and its variation can be depicted through a specially developed real estate risk indicator, which combines the individual situation of each property with mathematical and statistical procedures with regard to the market parameters.

- **Liquidity Risk**
  Corresponding risks are by daily monitoring of the liquidity situation, through the daily monitoring of sales figures and the holding of a liquidity enhancing measures (sales lists, credit limit, etc.), as well as by stress scenarios and risk considerations, which regularly updated plans build on, taken into account. Regulatory provisions are also risk-limiting.

Based on identified risk-bearing capacity of the individual funds, limits are assigned to these types of risks and regularly monitored by their load. The impact of decisions on the risk-bearing capacity of the Fund can be estimated in advance and included in the decision-making process.

Product-Level - Sustainable corporate management as a result from the interaction of sustainable products, social responsibility and economic efficiency, compliance and corporate governance

The foundations for sustainability of the real estate fund products are placed, as shown above at the level of 'production' which is to complement, creating a sustainable business model at the level of the producer on the part of the capital management company so at the product level.

3. Results and Conclusion

Sustainable corporate management is in addition to the responsible actions towards customers with the appropriate design of the products also to redeem this promise towards tenants, employees, environment and society. For this purpose, it is not sufficient that sustainability aspects are taken into account only at the production level. Especially for financial products today also the sustainability of the provider is asked its integrity in addition to the product itself in the sense of actually sustainable to offer the products. A process that applies through all the levels of a company.

If companies such as investment management companies and others move as a provider of open real estate funds in the represented grid of the legal provisions, a competent strategy including supporting internal consulting and a sufficient profitability, they will also continue as solid recognized products can transmit, and consist in volatile markets. Credibility and consistency in the policy are crucial for sales partners and investors.

These are the conditions that ultimately the producer itself in terms of its shareholders and other stakeholders sustainable stock and can meet the expectations placed on him in the future. Continuous development of responsibility and adaptation to the market conditions on all levels of a company to business management makes an important contribution to the increase of corporate value and stands for a sustainable business model in terms of customers, shareholders and the environment.

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Improving energy performance: many small interventions or selective deep renovations?

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Summary

Recent findings from a monitor containing around 1.5 million homes in the Dutch non-profit rented sector show that the energy improvement pace in the sector in the last years is too slow to meet the nationally agreed level in 2020. The findings also show that the improvement of the energy performance of the respective homes is mostly carried out in small steps: in many of the improved dwellings only one single measure is applied, and deep energy renovations are rare. Advocators of such renovations nevertheless believe that such improvements are the most appropriate way to substantially reducing energy consumption and argue that the developments and proliferation of energy renovation concepts is the best way forward. Others, however, do not see this as realistic and argue that reality forces us to proceed on the path of small interventions. This study sheds more light on this debate from the way in which housing providers conceive and implement their portfolio and asset management strategies. From these investment policies, it seeks explanations for the dominance of the small interventions and investigates the room for a more concentrated allocation of budget resources. To this end, housing providers with different energy investment policies are selected and interviewed. Results show that current practice leaves little room for deep renovations, but that a more mixed picture of small and deep interventions may be expected when zero-energy renovations grow out of their experimental status.

Keywords: portfolio management, asset management, non-profit, housing, energy performance

1. Problem statement and research question

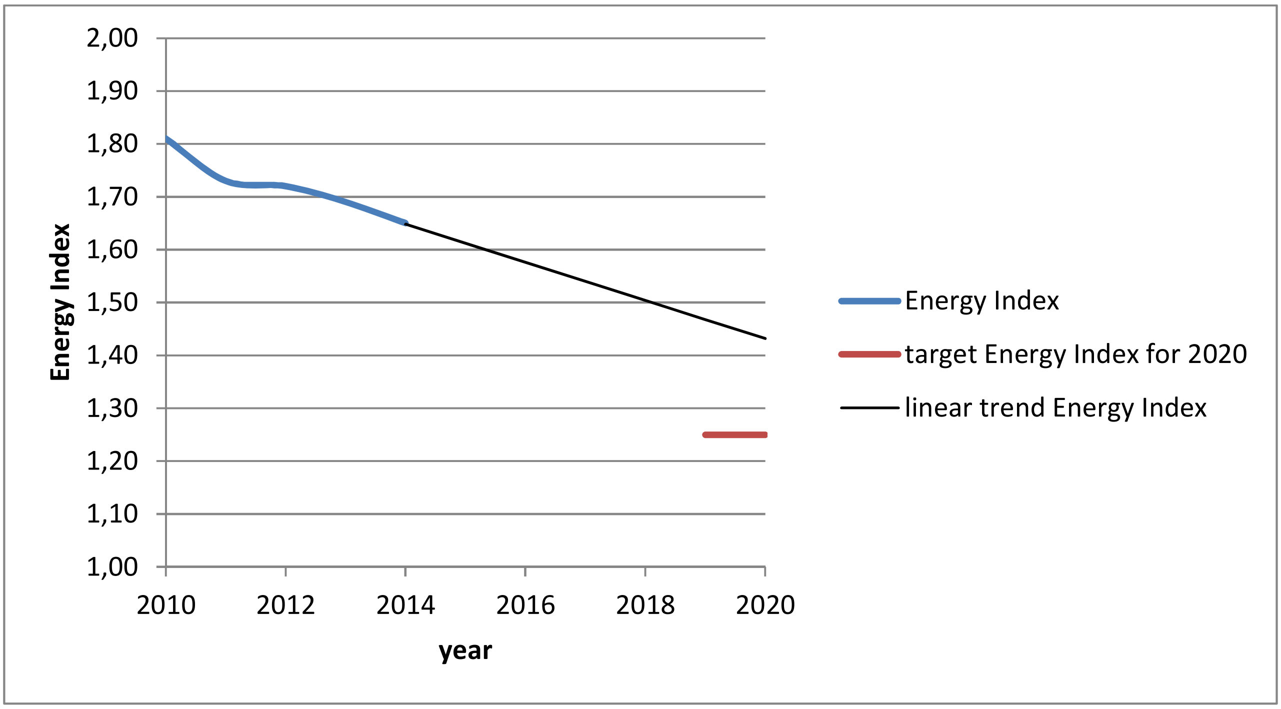
Since the implementation of the Energy Performance of Buildings Directive (EPBD), energy efficiency is a matter of great concern in the Dutch non-profit rental housing sector. In 2008 *Aedes*, the national umbrella organisation for housing associations (which almost exclusively own the non-profit housing stock in the country), the Ministry of Housing and *Woonbond,* the national tenants' union, signed a covenant in which, among others, a 20% reduction on the total gas consumption in the non-profit housing sector over the years 2008-2018 was agreed.

In 2012 the 2008 covenant was repealed. The covenant that came in place (and that is still in force) is stricter and makes use of the Energy Index (*Energie-Index*), a dimensionless unit that denotes the energy performance of a building according to the official Dutch calculation method. The value range of this unit approximately ranges between 0 and 4, in which 0 is energy neutral and 4 is extremely energy inefficient. The 2012 covenant states that in 2020 the average Energy Index of all homes of the Dutch housing associations must be 1.25, which is within the bands of energy performance rate B. In the Netherlands categories ranging from A++ (very high energy efficiency) to G (very low energy efficiency) are used. Rate B can thus be seen as a high standard.

In the 2008 covenant it was also agreed that Aedes would develop a database to monitor the improvement of the energy performance of the Dutch non-profit rental housing stock. This monitor has been called SHAERE (*Sociale Huursector Audit en Evaluatie van Resultaten Energiebesparing* – in English: Social Rented Sector Audit and Evaluation of Energy Saving Results). Since 2010, when the monitor became operational, housing associations report their stock to Aedes in the beginning of each calendar year accounting for the situation on December 31st of the previous year (e.g. in the beginning of 2015 for December 31st, 2014). Housing associations are not obliged to participate in the monitor, so the number of homes for which data are available varies from year to year. Nevertheless, the monitor covers each year a large part of the sector, approximately 50-60%.

Results from the monitor show that the improvement of the energy performance of the non-profit rental housing stock is too slow to attain the agreed level in 2020. If the current improvement pace would continue until 2020, the Energy Index will be 1.41 by then (see linear projection in figure 1).

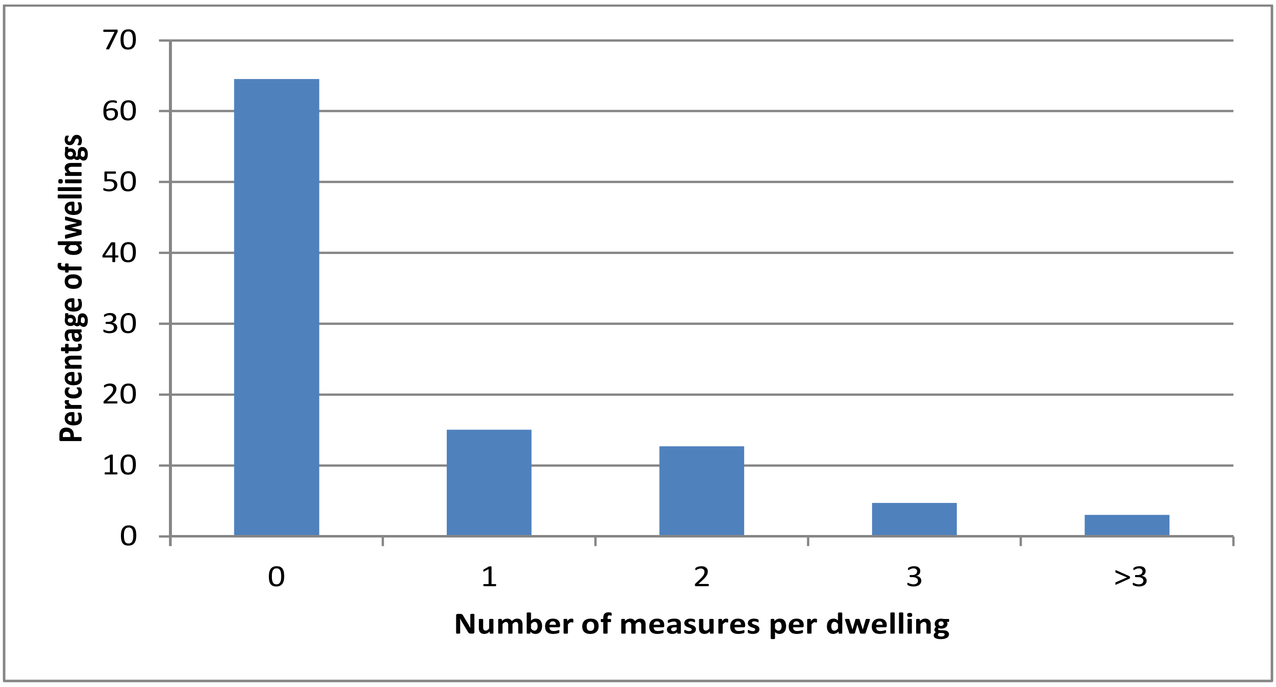
Figure 1: Development of the average Energy Index in the Dutch non-profit housing sector, 2010-2020



Sources: [1], [2] and [3]

Results from the monitor also show that many homes have been improved in a relatively short period. In the years 2011, 2012 and 2013, 35.5% of the homes have undergone an improvement of the energy performance (Filippidou *et al.*, 2015).

Figure 2: Number of measures per dwelling in the Dutch non-profit housing sector, from the end of 2010 to the end of 2013



Source: calculations on SHAERE by OTB, Delft University of Technology

At the same time, however, deep energy renovations are rare and most improvements are small. In half of the improved dwellings, only one single measure is applied. In only 3% of the homes more than three measures were applied (see figure 2). Advocators of deep renovations nevertheless believe that such improvements are the most appropriate way to substantially reducing energy consumption and argue that the developments and proliferation of energy renovation concepts is the best way forward. Others, however, do not see this as realistic and argue that reality forces us to proceed on the path of small interventions. This study sheds more light on this debate from the way in which housing providers conceive and implement their portfolio and asset management strategies. From these investment policies, it seeks explanations for the dominance of the small interventions and investigates the room for a more concentrated allocation of budget resources.

2. Method

For the study 12 housing associations have been selected and interviewed. It was chosen for interviews, because this research method gives room for expressing the underlying opinions, views and contexts for the decisions on energy investments. From an earlier study, held in 2012 ([4] and [5]), we expected that a big minority of all housing associations had not formulated an energy investment policy, which makes it plausible that these organisations do not have many own experiences about various ways to invest in the energy performance of their stock, and therefore are less appropriate as respondents for this research. For this reason, we did not apply a random selection, but selected housing associations from which we expected more advanced energy investment policies. We chose them among the members of an existing platform on technical management and also from a group of housing associations that, according to an own telephonic investigation done in 2012, had improved the energy performance of a relatively big share of their housing portfolio. We selected organisations that had carried out deep renovations and organisations that had not, in order to ensure that housing associations with different energy investment policies were represented. At each organisation, we spoke with persons which were responsible for the implementation of energy policies into investment planning, for example heads of real estate planning. The topics in the interviews were:

- the energy policies and ambitions of the respective organisation;
- the types of investment (notably renovation, planned preventive maintenance, void repairs and possible separate investment 'flows') in which the energy investments are included;
- the room for selective deep renovations.

The interviews took place in October 2015; one interview was conducted in November 2015.

3. Results

Table 1 presents the targets of the interviewed housing associations regarding the energy performance of their housing stock.

Table 1: Aims of the interviewed housing associations regarding the energy performance of their housing stock

Aims	Number of housing associations interviewed*
Average energy performance label B for the whole portfolio	4
Average energy performance label C for the whole portfolio	1
Improve at least x dwellings by at least 3 label categories or improve them to energy performance label B	1
30% of the dwellings will have energy performance label A of B	1
At least energy performance label C after an intervention	1
Phase out dwellings labelled E, F and G	4
Phase out dwellings labelled F and G	3
Reduce CO_2 emission by 25%	1

* Because housing associations can have multiple aims, the sum of the number of housing associations in the table is higher than the number of housing associations interviewed.

Phasing out the most inefficient homes is relatively popular among the interviewed housing associations: 7 out of 12 housing associations aim at this. Also relatively often mentioned (4 times) is to attain an average label B for their housing stock. With this aim the respective housing associations apply the national covenant agreement of an average label B for the national stock directly to themselves. Some housing associations, however, stated that they had lower targets (such as an average of label C), because their financial means would be insufficient. The years in which the aims have to be attained vary between 2018 and 2025.

The moments at which the interviewed housing associations take measures to improve the energy performance of their homes is presented in table 2.

Table 2: Moments for energy investments as mentioned by the interviewed housing associations

Investment types	**Number of housing associations interviewed***
Planned preventive maintenance	9
Refurbishment / renovation	10
Void repair	5
At a ‘natural’ moment of replacement	all 12

* Because the housing associations include their energy investments in different investment types, the sum of the number of housing associations in the table is higher than the number of housing associations interviewed.

Except from the replacement of boilers and so-called “open” heating installations (e.g. geysers, gas heaters) energy investments are combined with other more or less planned forms of investment, notably renovations (mentioned by 10 out of the 12 selected organisations) and planned preventive maintenance (mentioned 9 times). Combination with void repairs was also mentioned, but less often (5 times).

Important to note is that housing associations can be highly selective in the measures that they take: building elements are usually replaced at the end of their lifespan, meaning that early write-off hardly takes place, even if this would result in a notable improvement of the energy performance. So, unlike table 2 could suggest, ‘natural’ moments of replacement must rather be seen as a criterion for selecting measures than as an additional investment type. Especially this can be an important explanation for the small number of measures per dwelling.

The interviewed housing associations think different about including deep energy renovations. Some of them reject these investments, mostly because of the costs, others argue that different homes should be (and actually are) treated differently, and argue that deep energy renovations can be executed if the technical and market prospects of the respective dwellings allow this. These organisations carry out experiments with zero-energy renovations or plan to do so in the near future.

4. Conclusions

The regular investment practice seems to be a good explanation factor for the overall picture of small steps in the improvement of the energy performance of the non-profit housing stock in the Netherlands. Planned preventive maintenance and void repairs are not very suitable for large-scale investments. Renovations do, but rarely take place, too little to have a serious impact on the average number of measures per dwelling. Although many housing associations are, in their official policies, inclined to make big steps forward in the (average) energy performance of their stock, they seem to strongly dislike early write-offs and additional investment schemes. In practice, energy investments have to be fit in regular investment schemes and have to follow general decision criteria such as the lifespan of the respective building element and the market position of the respective dwelling. In their approach, the main choice is *not* between many small interventions or selective deep renovations, because all housing associations broadly invest in their portfolio. The question which divides the housing associations is rather: which investment room is available for deep retrofits as well?

The current investment practice of the interviewed housing associations shows little room for acceleration of energy performance improvement in the non-profit housing stock on the short term. Deep renovations are mostly seen as innovations, which could be suitable for individual experiments, but not (yet) for wide application. This may change when this kind of renovations will be more generally recognised, but to date this is not the case. It would be helpful that zero-energy renovations, which are still in their infancy, but are developing rapidly, will continue to follow the current trend of decreasing expenses. However, it must be admitted that even then, (pre)financing of the measures remains a barrier for investments (e.g. [6]). For this reason, a step-by-step approach (see e.g. [7]) could be more practical, although this approach bears the risk of preventing further improvements. Further research is needed to assess the size of this risk and the efficiency of the step-by-step approach compared to other approaches.

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Improving energy retrofit strategies with definitions of human interaction parameters in residential building

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Summary

Retrofitting is an effective method for improving energy efficiency of the existing buildings. Building energy retrofitting depends significantly on the criteria affect health, productivity and comfort of the occupants also used for the indoor environment (temperature, ventilation and lighting) and building (including systems) design and operation. In the retrofitting, the interaction between psycho-physiological and sustainable built environment should be taken into account, as well as considering features related to energy performance and architectural aspects, and also human needs and well-being.

This paper presents a review of the most common strategies for renovation of buildings and suggests some possibilities based on the energy performance and the interactive potential for human well-being. The main objective of the project is to establish a guideline for energy retrofitting assessment. More analytical methods are needed to discuss about variable parameters which play a significant role in the creation of a proper assessment for designing and evaluating energy retrofitting systems that addresses the complexity of human needs in buildings. It seems that unfortunately existing retrofit perspectives are insufficient. As a result, this research aims to create such an effective and practical basis by considering the relation between different technical parameters and human well-being.

According to the existing literature, upgrading U-values of a building envelope and windows is the most approaches in many retrofitting strategies. Replacement of the windows is attributed to reduce the heat and energy demand. However this strategy needs to include the design elements depending on window's condition which is consequences of physical measures such as size, type, orientation and other elements of a window. The impact of these elements on energy performance and more importantly on human comfort, health and well-being is clearly obvious and has to be considered. While, this method offers benefits regarding managing and optimization of a building retrofit project, but still a wide range of studies are needed for an integrated assessment method.

The goal of this paper is offering a deeper insight into retrofit perspectives in order to reinforce the links between technical performances and other fields that deal with psychophysics or related to comfort-based and well-being aspects of human life. This goal includes some different performances of a building, like performance in lighting or thermal comfort. Each performance should be studied in terms of its relevance and interdependence on user satisfaction. This research reviews

the performance of a building's elements regarding human needs. Although a great deal of this objective and development toward the advancement of the systems approach remains to be accomplished.

Keywords: retrofitting, energy efficiency, human needs, integrative performance, windows replacement

1. Introduction

Existing buildings are responsible for about 80-90 % of energy consumption, meanwhile new buildings just account for a low proportion of existing buildings [1]. Most existing buildings fail to satisfy performance and energy efficiency expectations [2]. Energy retrofit of existing buildings is an effective way to increase energy performance and as a result, enhancing the quality of life for their habitants.

Furthermore, the huge impact of buildings on our lives is a major concern. Buildings are considered as one of the most important parts of our lives, since regularly the highest proportion of one's life (up to 90%) is spent indoors [3]. Most of the existing building are no longer meet today's demands including new expectation of building's life and performance, so they have to move beyond not only energy efficient renovation but also across new generation needs [1-3].
A retrofitting can prolong the life of an existing building and even improve its technical performance by adjusting space for better quality of life. In this case, the role of retrofitting is creating an opportunity for existing buildings to adapt for comfort-based and well-being disciplines, stimulatingly.

Energy retrofitting of the existing buildings focuses on the improvement of heating, cooling, and ventilation systems [1-8]. However with an increasing demand to the fulfill occupants' needs, it is essential to expand focus on physio-psychological well-being as well. This paper investigates some approaches to reach out possible improvement of technical measures due to energy efficient retrofit strategies with a detailed picture of the well-being. This paper presents a critical review of the façade retrofitting of the existing buildings and discusses the most common strategy by replacement of the existing window.

2. Current energy retrofit strategies and approaches

Renovation of the existing building stock is expected to perform the main task in Europe's construction perspective in the future, and it is widely reflected with a focus on the energy efficiency improvement of the building envelope [4-7]. Renovation offers a substantial chance to improve the technical performance of the existing buildings and an opportunity for architecture, including upgrading quality of life (functional performance). Sustainable renovation is renovation that meets the needs of the present generation with the ability for future generation to meet their own needs [1,8].

A high number of existing buildings in Europe built around 1950-1980 [1,7], this seems those have not been achieved energy efficiency strategies and policies, but rather on adaptation to technical, architecture and social aspects in particular with the human needs.

Building façade components and openings in the façade building are one of the main concerns in architectural elements to support energy efficient retrofitting. Although, nowadays retrofitting of the existing buildings has become a key concern in existing studies to decrease energy demands, improving the efficiency and sustainability of these retrofitting strategies still remains in the primary stages and a complicated challenge [5,7-8]. Energy retrofitting could be a key to progress towards enhancing quality of life in the existing buildings. The evaluation and priorities of different energy retrofitting strategies depend on the chosen criteria. The most common applied criteria have technical or economic targets.

Several research studies on design process have shown that the increasing notion to the increases building occupants' satisfaction regard to the visual comfort (Boyce et al., 2006), natural and mechanical ventilation. Furthermore, good design of buildings provides side effects for building occupants ranging from improved health and wellbeing to increased quality of living space (Wout van Bommel, 2006; Veitch et al., 2007) and higher productivity (Heschong, 2002). However, most of the relevant retrofit activities have focused on improvement aspect in the existing buildings regarding thermal comfort related energy saving for heating and cooling. In regards, we have expressed specific concern about lighting and ventilation parameters.

3. Replacement of the windows and principles in building retrofitting

In general, natural light, ventilation and fresh air can be provided by windows in the buildings. Moreover, windows are considered as a connection between outdoor environment and indoor space. In particular, it is important to know which parameters are currently used to improve renovation strategies. The common renovation practices include replacement of the windows with a focus on reducing energy demand [1-8]. We propose to follow replacement of the windows strategy regards dynamic interaction of a window in a living space as a space that is used for inhabitants.

The considerable effect of a window on both energy consumption and indoor comfort is clearly obvious. For example, the size of a window provides more or less daylight in a space; they could also affect visual comfort and the energy needed for heating or cooling and lighting. So, it is important to explore how window retrofitting can plan and how affect the energy needed as much as it can contribute to achieve human needs.

Since, various studies investigated the potential of the windows [1-7], in order to achieve thermal comfort (heating), natural ventilation (cooling) and natural lighting (electrical energy) in design process. But, available strategies in retrofitting of the windows involve just increasing the energy performance of the windows with a focus on U-value of the window and the insulating quality of the windows. A typical new building design employs the building shape, the surroundings, orientation and glazing area to climate adaptation and providing human needs, however the current activities on energy retrofitting of windows only focus on high performance windows. According to the literature, window renovation takes account for the following objectives:

- Minimizing of thermal transmission losses
- Airtightness improvement
- Windows with low U values
- Integration of shading devices

4. Configuration of influencing parameters of a window

In fact, windows have expressed a significant role in measurable criteria for delivering light and air in the buildings [9,12,19]. On the other hand, they result an assumption about living spaces [9-10]. A number of relevant parameters on the potential of the windows have been conducted, in order to achieve thermal comfort (heating), natural ventilation (cooling) and natural lighting (electrical energy) [9-18].Considering influencing parameters, different measures can be classified according to dimension, orientation, direction, form and even type of the opening of the window. The improvement considers thermal performance, lighting aspect and climate adaptation.

Windows characterize energy consumption, visual and indoor comfort patterns in a building. Choosing a window size is among many fundamental parameters which should be selected in the early stage decisions. Therefore, determining optimal characteristics for building retrofitting performance is also essential. Multiple aspects must be considered at once in order to accomplish human needs and well-being [10-11]. Even though, most research efforts are dedicated to find out optimal properties of a single element for only one purpose.

Optimizing windows for only low energy consumption cannot include criteria representing human needs. Therefore, an elaboarted retrofit strategy is needed, which takes into account different options such as glazing type, climatic elements, visual options, shade and natural ventilation opportunities.

4.1 Daylighting for human well-being

Without a doubt, one of the main tasks of a window in a building can be providing daylighting [10,13]. As far as daylighting is concerned not only as an important target to reduce electric lighting and energy consumption, but also is coupled with a multifaceted capability to meet human health and well-being. How the interior space can be better in daylighting has promoted an interesting debate about the perceptual quality and functional presentation of a space [14]. It accommodates the occupant's visual demands and their experience to connect with the outdoor phenomena [15-16]. Daylighting systems have been evaluated through some indicators, involving illuminance and glare [14]. However, assigning importance of values to each visual factor and their interaction with occupants requires further exploration. The window shape, size, position and ratio on the façade make up a set of impact factors. The analysis of daylight effect is meant as presenting either visual or unvisual effects in terms of how well human needs are met [14-16].

When we ensure about the state of visual comfort, typically we concern illuminance level in the interior space to guarantee the visual comfort [14,18]. To reach light and health, a deep understanding of optimizing building envelope including window elements improvement is needed (physical elements of window, orientation, size, position, forms and shape, number of windows and window ratio and shape). Realizing these needs requires an integrated retrofitting process with considering effective daylight in building renovation strategies.

4.2 Healthy lighting

Reinhart et al. (2011) developed an improvement and understanding of light needs in a design process, and others [13-16,18] declared light as a basic need for each person. The need to exposure to light is considered as a primary need satisfy for healthy living needs and well-being in the buildings [14,18]. How well an existing space is providing and performing daylight is linked to an opportunity to meet human needs [14].

Obviously, daylight exposure has been regarded as a major focus in many investigations [14-16,18]. The main factors in daylight performance are performed in how well each task will be supported. Moreover, recent findings have increased attention to the non-visual effects of light. Andersen (2015) employed a simulation method to assess daylight performance and a comprehensive framework for dynamical effects of daylight which regards to complex level of human needs [14].
But, among existing renovation strategies, very few analysis evaluated daylight as an important insight in human health and well-being. Table 1 summarizes significant elements which have the possibility of evaluating daylighting performance.

Table 1: summarizes measures for successful energy retrofitting regarding natural lighting

	Window element	Technical measures	Strategies	Performance	Cost performance
Natural light	Orientation Position Size Form and shape Number and ratio	Luminance averages and ratio Daylight glare probability Solar gain	Climate adaptation Daylight design Passive design Architectural renewal	Reduction of Electrical energy consumption Daily and seasonal performs Sleep wake cycle Thermal comfort Exposure effect Eye movement Dynamic viewed scenes Therapeutic effect Visual comfort Light quality Perceptual quality of indoor space Better function performance Human performance, mood and sleep quality Subjective alertness	Health cost reduction Energy cost reduction Property values

4.3. Window efficiency for natural ventilation

Studies by Vanhoutteghem et al. (2015) considered advantages of using natural ventilation in the inside the building through windows and façade openings. Furthermore, many studies have identified reduction in operating cost; better thermal comfort and indoor air quality result from effective window application [17-19,21-22]. The main function of application of natural ventilation in a building is not only reducing energy consumption and cost, but also providing comfortable, healthy and productive environment [16,17,19]. The efficiency of ventilation through the windows is demonstrated by window configuration, type, size, location and orientation. The ventilation performances of the interior spaces with windows are different from a significant to a negligible improvement. This presents the significant impact of windows in the renovation strategies.

Table 2: summarizes measures for successful energy retrofitting regarding natural ventilation

<table>
<tr><th></th><th>Window element</th><th>Technical measures</th><th>Strategies</th><th>Performance</th><th>Cost performance</th></tr>
<tr><td rowspan="8">Natural Air</td><td>Orientation</td><td rowspan="3">Air movement
Air’s velocity
Air pressure
Air flow
Air temperature
Outdoor air velocity</td><td rowspan="8">Climate adaptation
Wind sides adaptation
Passive design
Architectural renewal</td><td>Delivering air flow into different rooms</td><td rowspan="8">Health cost reduction
Operational cost reduction
Property values</td></tr>
<tr><td rowspan="2">Position</td><td>Comfortable indoor environment</td></tr>
<tr><td>Better air quality</td></tr>
<tr><td>Size</td><td rowspan="5">Interior air fellow
Air flow direction
Types of natural ventilation
Air distribution
Airflow pattern
Level of humidity
Air flow quality
Fresh air generation</td><td>Effectiveness of natural ventilation</td></tr>
<tr><td>Form and shape</td><td>Adequate Interior air fellow</td></tr>
<tr><td rowspan="3">Number and ratio</td><td>Better human activity environment</td></tr>
<tr><td>Removing moisture from indoor environment</td></tr>
<tr><td>Modify indoor temperature</td></tr>
</table>

5. Discussion

Enhancing the quality of life is proposed as a concept that provides interacting psychological and physiological aspects to meet human needs in the forms of technical performance. This paper investigates a selection of opportunities based on comfort and well-being linked to building techniques such as lighting performance, thermal comfort and indoor space quality. It is clear from the existing literature that many retrofitting systems are quite similar in their approaches. The most common types are passive strategies such as insulation of the envelope and replacement of the windows and air sealing [1-8,13,15].

In order to define energy retrofitting performance on the basis of occupant satisfaction and measures which must be obtained, an approach to provide a list of indicators for considering ways that in them strategies may support human needs and well-being have been suggested [20-21].
The analysis of human needs is followed by different scales of analysis at which human needs may be concerned. In this section we proposed a list of the human needs to use as the new insights for setting a framework of decision support in the retrofitting assessment. We could demonstrate three objectives of providing opportunities for human needs, as follows:

- comfort based
- healthier building environment
- delightful spaces

It is difficult to find a multi-faced study which includes configuration of different possible parameters of a window’s retrofitting and the integration of these to the retrofit strategies. Demonstration and unweaving the role of a window and its effect on an existing building can highlight some significant aspects that must be taken into account during renovation process (shown on the Table 4). Assessment target is the extent to which human needs are fulfilled. Whit this definition, the role of human can consider at three dynamic levels of human interaction in a space. This objective allows us to uncover:

- Potential interaction between human as an inhabitant and the building as a living space that has to provide a healthy environment.
- Possible elements that are enhance the quality of a building to meet human needs as a user of a space that serves a function and human’s task.

- An opportunity for delightful space, the question is how retrofitting deals with potential of technical and architectural aspects to generate an atmosphere to enhance human interest and provide emotional and empirical delight.

In order to operationalize the measurement of fulfillment of human needs, we have linked the human needs to technical measures and also performance aspect according table 1, table 2 and table 3.

Table 3: Assessment definition

	Opportunities on window retrofitting
Energy Performance and comfort	Thermal comfort
	Decreasing energy use
	Delivering air flow into different rooms
	Effectiveness of natural ventilation
	Adequate Interior air fellow
	Removing moisture from indoor environment
	Modify indoor temperature
Happiness and well-being	Comfortable indoor environment
	Better air quality
	Better human activity environment
	Daily and seasonal light performance
	Dynamic viewed scenes
	Visual comfort
	Perceptual quality of indoor space
	Better function performance
Health value	Sleep wake cycle from daylight
	Exposure effect of daylight
	Eye movement
	Therapeutic effect of daylight
	Human performance, mood and sleep quality
	Subjective alertness

We used the retrofit strategy of the window replacement to analyze the goals for a renovation system. The desires for the strategy are recognized according the table 1 and table 2. Sustainability is High level objective of the different renovation strategies. A renovation strategy usually has a process which provides system design, statement of requirements regarding existing condition, operation and systemization of system, mounting and installation. Objectives are assumed in every phase with relative user. A renovation strategy may have several possible goal states. In this case, we need to identify and organize goals from the variation of the requirements. A goal-based approach could support to model performance complexity such as different performance perspective for energy performance and human well-being or even in particular to adapt individual target performance.

So far, this paper, briefly discussed goals upon well-being and health of habitants. The goals are built from the assessment definition in table 3. In regards, the study discuss goals to categorize strategies and in the next step goal evaluation for dealing with other techniques. Respectively, needs to record how this goal provides a desired condition, does intending this goal depend on other goals and does target goal remains in its true condition with or without support of other goals. A goal-based analysis can help defining and categorizing the requirement structures and investigating goals. It can support decision-making with multi-objective framework. The aim of the current study is to illustrate the structure of such a decision-making support and potential to operationalization by software. While the most of current assessment for building renovation emphasizes technology development. Goal-based methods are applied to stress the need to categorize and drive the goals and the level-goal for the system; these goals appear to realize the objectives from different perspective. Goals must be defined from various user types including building owner, occupants, investors and government officials. We have to decide how and when goals are derived and belong to which purpose of the system.

To achieve energy performance to support human needs, the window replacement and the renovation strategies need to optimize over well-defined issued and include renewal, improvement of the window or modification of the envelope openings. In addition, the optimization is consequences of optimization in use and function of building spaces which can be applied to the different goals and can be improved by adjusting existing architectural condition.
Yet in a renovation strategy, improvement of the envelope is the major priority to energy saving and reduction of CO2 emissions. It is important to mention that energy simulations will support human well-being so far architects and building engineers know what have to intend, change and look for.

6. Conclusion

Energy retrofitting represents a multi-dimensional concept that could provide opportunities to meet human well-being in terms of usage, function and technical design. The most common in use strategies to increase energy efficiency are planning to replace windows. Even though, energy efficient retrofitting can achieve development and improvement of building spaces.
Current study has provided an overview to analyze possible influencing measures to evaluate existing building retrofitting strategies. Also, this research summarizes potential elements for energy efficient retrofitting integrated with well-being and human needs.

This study has found that, it is very important to design a proper window as a key element that represents the most basic resource for natural light, visual view and ventilation inside the buildings. We have addressed challenging sides of window replacement method and presented a new methodology to optimize strategies for façade retrofitting. Likewise, it is important to realize that the largely potential criteria could be related to orientation, shape and size of a window in regards the dynamic interface between exterior and interior spaces.

Finally, the research has introduced the concept of being able to integrate technical criteria and energy efficiency and human needs, through an integrated definition. Typical and simple design problems are posed around the relative impacts of measuring human needs. In order to remove these limitations in building design, interactive and perceptional analysis and practical methods such as retrofit choices should be tested and challenged.

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Increase in Efficicency and Quality Control of Construction Processes through Off-Site Fabrication

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Summary

This paper compares and assesses modular prefabricated building systems according to material use, process efficiency, ecological potential, i. e. sustainability of construction processes, and market relevance. To provide a holistic overview of the current market situation, two best practice examples are examined and evaluated. Covering favourable materials and prefabrication methods essential for the development of sustainable, cost-efficient housing, selected projects comply with current and future energy efficiency standards in construction. Due to systemized planning strategies and optimized utilization of materials, recyclability properties of buildings and their parts enhance significantly. Furthermore, prefabrication processes contribute to the reduction of waste. Beyond achieving ecologically and economically advanced processes, prefabrication enables technical improvement of manufacture by simultaneously increasing the quality buildings and their parts.

Keywords: Off-Site Construction Processes, Prefabrication, Integrative Planning, Resource Efficient Fabrication

1. Introduction

Rising global population growth and urban migration rates are indicators of a continuously increasing demand for housing. Higher building densities and compact building designs are essential to reduce associated land use as much as possible. This paper describes how current building production techniques must rapidly change in order to accommodate these factors.
Examining methods of the prefabrication industry, key aspects of modular building processes for residential construction are conveyed and highlighted. Serial manufacturing methods and automated processes are assessed and evaluated to categorise indicative workflows. Thus, transfer strategies of technological analogies for industrial construction are defined.

3.1 Background

Studies conducted by the United Nations Organisation (UNO) show that urban migration rates will increase with about 75 % of the world population living in cities by 2050. Therefore, today's building concepts need to allow for both, higher densities within the urban environment and institute environmentally friendly construction methods. [1] A holistic sustainable design approach requires the consideration of fabrication and construction processes as well as materialization of buildings and components. In order to achieve resource efficient manufacturing methods, planning strategies have to consider and evaluate the distribution of on- and off-site processes. Beyond increasing control of work sequences and quality of execution, procedures contribute to ecological advancements and the enhancement of cost- and time efficective project realisation.

3.1.1 Housing Situation and Market Overview

The German prefab industry is one of the leading global manufacturers in the segment of prefabricated housing. The industry's main focus remains the single-family and low-rise housing segment. Representing about 15 % of the German housing market, the popularity of prefabricated residential construction, particularly located in suburban areas, has grown about 2.5 % within the past 20 years. [2] In intra-urban areas, conventionally built multi-storey structures dominate the built environment. The following paper evaluates modular prefabrication and associated construction technologies based on

- Material use
- Integrative design approach
- Applicability in multi-storey building structures

The majority of prefabricated, residential building stock remains the single-family home segment in timber construction. As shown in Figure 1, conventional, wet construction methods using brick, building stones or concrete cover approx. 84 % of the materials used for housing. The amount of 0.01 % buildings in steel is negligible. To generate a thorough and fundamental comparison of building materials and systems, fabrication and construction processes need to be evaluated. Validated statements regarding ecological, economical and technical qualities allow for direct transfer regarding manufacture and assembly of buildings and their components, thus contributing to the optimisation of building construction.

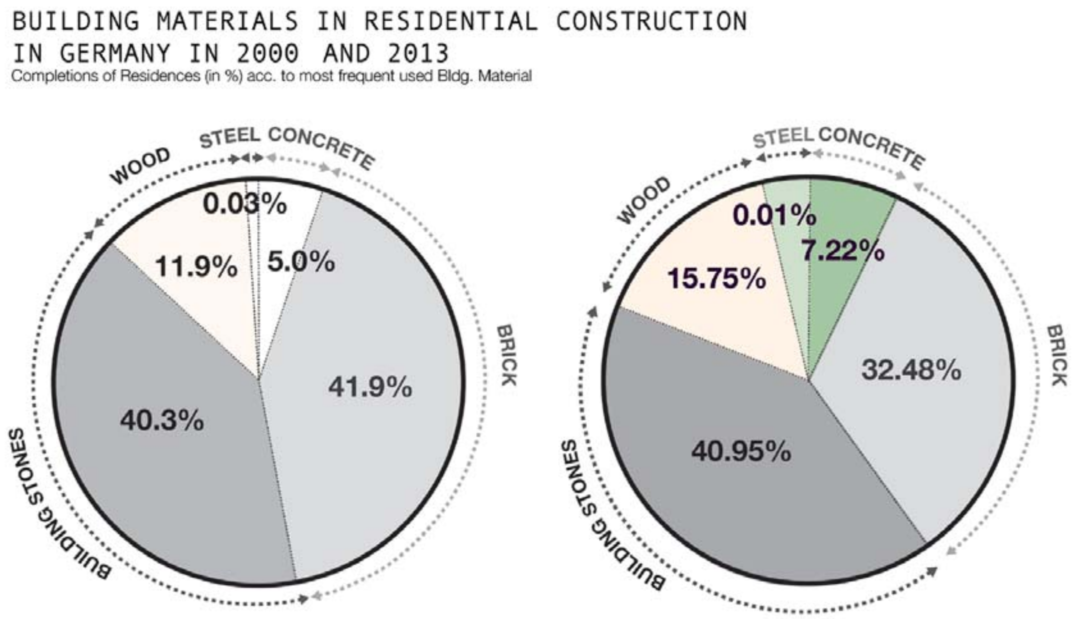

Fig. 1 Building Materials in Residential Construction in Germany in (a) 2000 and (b) 2013

3.1.2 Manufacturing Methods Using Wood Based Systems

The construction of an average sized prefabricated 140 m^2 single-family home takes about 15 tons of wood used for load-bearing elements, nonstructural components, and finishes. According to industry research, a CO_2 relief for the atmosphere of up to 27 tons can be accomplished. [3]
During the past decades, a predominant use of timber frame building systems for multi-storey housing becomes apparent. Requiring lightweight construction methods, systems developed continuously, and technological innovations regarding material build-ups and the integration of subsystems enabled enhanced assembly and installation sequences. More recently, new wood products, i. e. cross-laminated timber (CLT), were introduced into the market, contributing to advanced structural solutions and building typologies.
Compared to solid construction methods, the lightweight wood-based systems improve a building's carbon footprint. On the one hand, the amount of energy required for material production and processing is comparatively small. Furthermore, the material enables to store large quantities of CO_2. In comparison to industrially produced building materials, wood extracts CO_2 rather than emitting it, hence eco-balance and GWP-values improve (Fig. 2). Due to sustainable forest management, the availability of the material will remain sufficient.
Compared to conventionally built dwellings of brick, stones, or concrete, buildings made of wood are 10 to 15 % higher in cost. However, a project's economical efficiency can be improved by accelerated construction cycles, achieving shorter manufacture and assembly times. Furthermore, the use of lean element sections provides an increase of net floor area, benefitting the economical status. Additionally, a high quality of elements can be achieved.

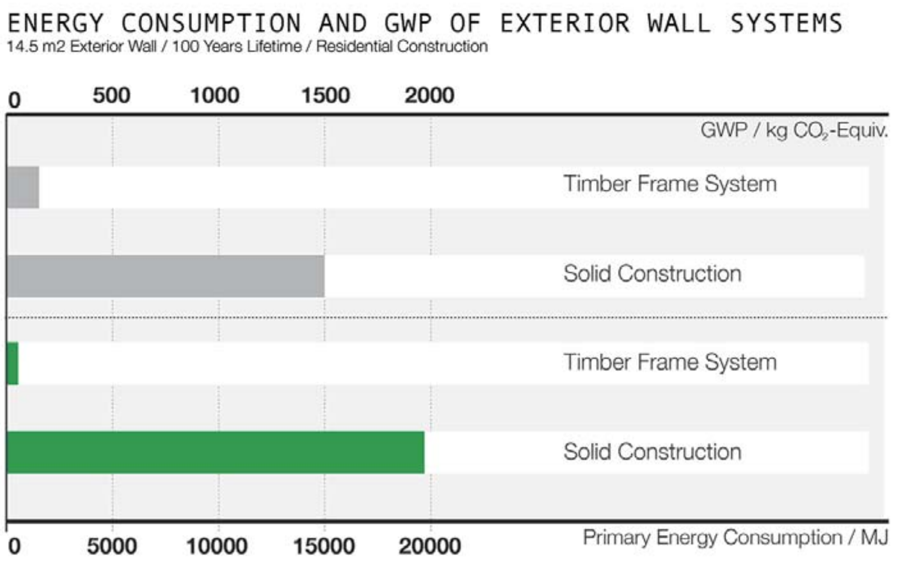

Fig 2 Energy Consumption and GWP of Exterior Wall Systems (14.5 m^2)

3.1.3 Potential of Precast Concrete Modules for Multi-Storey Housing

This paper evaluates the prefabrication potential of concrete and its applicability in multi-storey buildings. This material proves to be economically efficient, easy to produce and maintain, and precast elements are fast to assemble. Subsequently, advanced construction technologies and implementation methods emphasise considerable advantages for fabrication.

Nevertheless, resource efficiency aspects as well as limitations through fabrication and transport have to be considered when chosing the material and associated methods of construction.

2. Methodology

The following research compares two modular building systems. For a boarding house in Neuhausen (Germany), construction methods combine in-situ concrete and modular timber prefabrication. For the student housing block in Sant-Cugat (Spain), precast concrete cells are used to generate a two-storey building structure.
This paper focuses on the assessment of construction systems and material performances. Technical properties, behavioural aspects, and manufacturing and assembly processes of buildings and components are essential for the ecological, economical, and technological optimisation of buildings and their design. In the analysis, joints and transition areas of structure, building envelope and technical services are identified and exemplified based on outlined projects in modular construction. The manufacture of building components, following smart assembly and disassembly strategies, contributes to an efficient enhancement of building and construction processes.
Furthermore, the paper evaluates current methods of manufacture to generate advanced solutions for future building construction. Outlining the coherence of materiality and building structure, the material-specific case studies introduce industrial construction methods, highlighting prefabrication potential and applicability for multi-storey structures.

3. Results

3.1 THW-Bundesschule in Neuhausen (DE) 2014, Project Development: Bundesbau Baden-Württemberg rep. by Hochbauamt Reutlingen

The two-story boarding house of the THW-Bundesschule, an extension to an existing 1950 building ensemble, is located on a hillside in Neuhausen, near Stuttgart.
The original scheme proposes a combination of conventional in-situ concrete construction and precast cavity wall elements. Due to time and cost related deficiencies, a redevelopment of planning and building process was required. The resulting comparison between construction methods lead to increase the amount of prefabrication, introducing modular CLT-room cells in the scheme.

3.1.1 Building Information

Table 1 shows an overview of construction cycles and building data, relevant for the comparison of systems and the distinction between design approaches. On-site processes are divided into conventional work sequences, including site preparation and in-situ construction, and on-site assembly and installation of prefabricated parts, in this case the completed room modules.

Table 1: Construction Data

Construction Times	Duration Periods
On-Site Conventional	29/01/2013 - 29/02/2015, 24 Months
Off-Site Prefabrication	02-04/2014 Plg., 04-05/2014 Fabr. (5 wks.)
On-Site Prefab (Assembly)	02-08/06/2014, 6 Days

The following table shows general information regarding building dimensions, areas and mass, and construction costs. Furthermore, energy performance values, based on DIN 18599 and EnEV 2009 are shown. Energy values refer to the project’s total net floor area (NFA).

Table 2: Building Data

Building Data	Dimensions/Costs/Energy Performance
Building Dimensions (w*l*h)	13.4 x 41.5 x 10.4 m
GFA (Gross Floor Area)	2109 m^2
NFA (Net Floor Area)	1535 m^2
GBV (Gross-Building Volume)	7173 m^3
No. Levels	4 (L-01/00/01/02)
No. Units	30
Costs Modular	1 180 179 €
Costs Total	5 400 000 €
Annual Operating Energy	245 kWh/ m^2a
Primary Energy Consumption	306 kWh/ m^2a

3.1.2 Structural Concept and Assembly Strategies

The building bends along its centered axis, enabling an optimised orientation of the rooms. Each of the 14 m^2 bedrooms includes a bathroom, cabinet, storage and desk space each, and is laid out on a 3.65 m planning grid. Due to the modular structure, the bearing crosswalls consist of two 0.12 m CLT-layers and reach a fire resistance rating of F 30. Figures 3 a, 3 b, 3 c and 3 d show the rapid on-site assembly and installation sequence of the prefabricated units, which were finalised within six days.

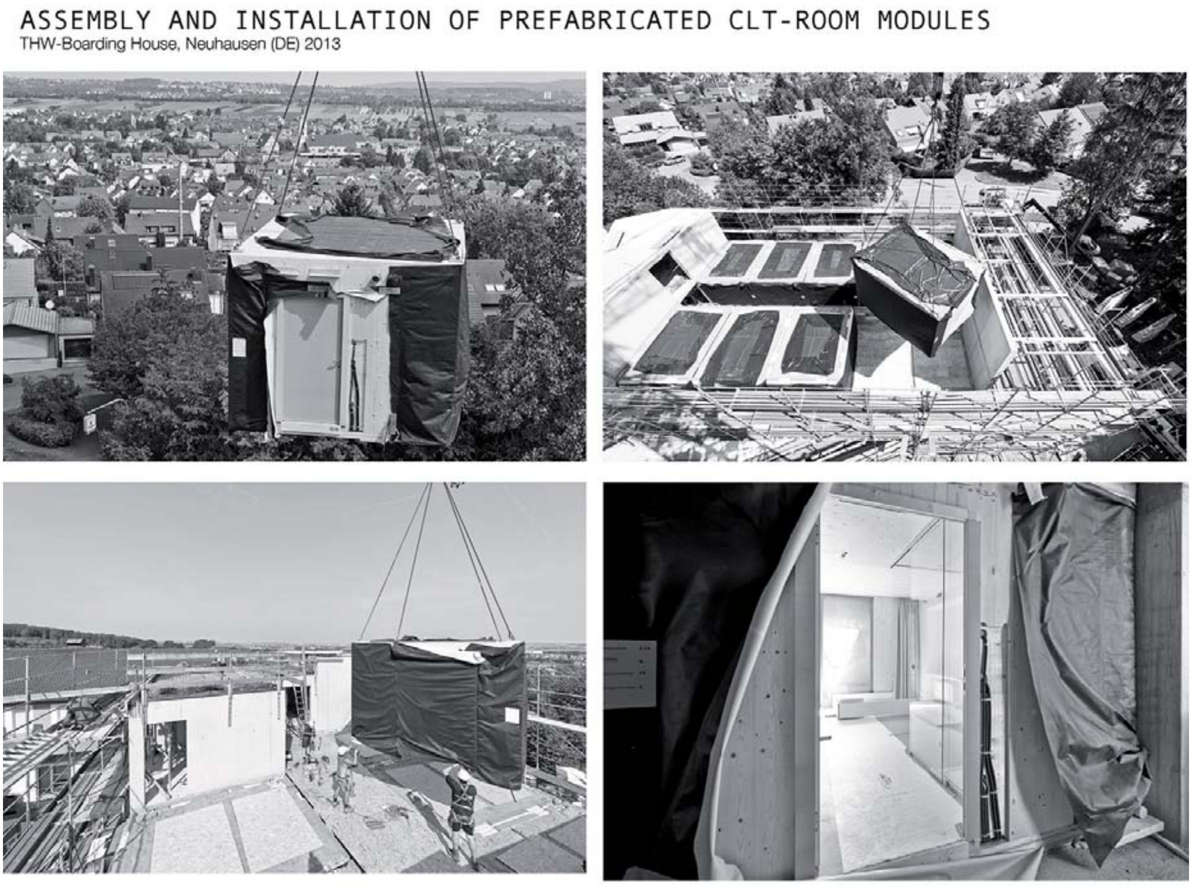

Fig 3 a – d Assembly and Installation Sequences of CLT-Room Modules

The structural concept combines in-situ concrete construction for core, bearing walls, and ceilings with prefabricated, structurally independent modular cells for the bedrooms. All technical supply rooms, recreation and sanitary facilities, a lobby, the restaurants including cafeteria, canteen, and a large kitchen are located on basement and ground floor level, while the 30 rooms of the boarding house are on first and second floor. The modular prefabrication of the hotel rooms not only bears economical and technical advantages, but also contributes to a resource efficient manufacture. However, energy use values for building operation increase significantly due to consumption of the ground floor facilities.

Fabricated and equipped off-site, the modules contain mechanical and technical supplies, the substructure of the facade, and internal partitions. Cladding and final external layer were subsequently applied on-site. All required connections for final on-site installation were provided.
Similar to the behavioural performance of solid components, the cross-laminated timber slabs of walls and floors enable sufficient bracing of the modules during transport and assembly. According to fire-protection standards, four to five cm filling above the structural plate is required, adding mass and further improving sound insulation qualities. Therefore, the final weight results at approx. 5 tons for each room module of the boarding house.

3.1.3 Summary

The application of modular timber construction has enabled significant advantages for the project. According to comprehensive cost estimates, the implementation of prefabricated bedroom units led to a reduction of total building costs, and allowed for saving of time and associated costs for rent paid to third parties. In comparison to the initially proposed precast slabs, the use of massive wood elements improved the ecological footprint of the building and contributed to interior comfort.

In contrast to the modular wood project in Neuhausen, a student housing project in Sant Cugat, Spain uses concrete cells to generate the double-storey buildings. Besides rewarding design and planning strategies, the project provides excellent ecological performance values.

3.2 Student Housing Campus Sant Cugat, Barcelona (ES) 2013 Architecture: N-Arquitectes, Project Development: Compact Habit

Organised within two opposite building blocks, the 57 student residences are located in Sant Cugat del Vallées, a town in the suburban area of Barcelona. The two-storey apartment buildings are arranged around an open courtyard. The precast concrete modules cover 3013.50 m^2 of the total 3101 m^2 GFA. These 62 prefabricated units include a few cells for common space, and are completely manufactured off-site. For delivery and final on-site assembly, the room modules were transported from the plant facility on-site using heavy load and special freight movements.

3.2.1 Building Information

Table 1 gives an overview of construction cycles and building data, relevant for the comparison of systems and the distinction between design approaches. On-site processes are divided into conventional work sequences including site preparation and in-situ construction and on-site assembly and installation of prefabricated parts.

Table 3: Construction Data

Construction Times	Duration Periods
On-Site Conventional	12/2008 – 08/2009, 8 Months
Off-Site Prefabrication	NN Planning, 04-05/0209 Fabr. (6 wks.)
On-Site Prefab (Assembly)	10 Days

The following table shows general information regarding building dimensions, areas and mass, and construction costs. Here, energy performance values are based on Swiss Minergie standards and refer to the building's total GFA (Gross Floor Area).

Table 4: Building Data

Building Data	Dimensions/Costs/Energy Performance
Building Dimensions (w*l*h)	28 x 75 x 6.5 m
GFA (Gross Floor Area)	3101 m^2
NFA (Net Floor Area)	2480 m^2
GBV (Gross-Building Volume)	9920 m^3
No. Levels	2 (L00/01)
No. Units	62
Costs Modular (incl.adj. buildg. pts.)	1 872 752 €
Costs Total	2 784 739 €
Annual Operating Energy	82 kWh/ m^2a
Primary Energy Consumption	88 kWh/ m^2a

The 57 apartments, consisting of reinforced concrete modules, each measuring 11.20 x 5.00 x 3.18 m and 39.95 m^2, include bathroom pod and balcony space. They were fabricated within 6 weeks using an indoor assembly line. Standardised dimensions, fixed widths and heights but alternating lengths enable resource and time efficient production sequences. Off-site manufacturing contributes to process control and improvement of a construction's energy management. The reuse of formwork provides significant economical advantages.

3.2.2 Structural Concept and Assembly Strategy

The structural framework of the modules is based on a planning grid of 0.90 m for each unit. Concrete ribs transfer vertical and horizontal loads. The tubular structure provides easy stacking of units without further support. The decoupling through flexible elements, that are located at the bearings between the cells, impedes direct sound transmissions.

Figure 4 a shows the structural framework of a concrete cell, highlighting maximum span dimensions. Figure 4 b illustrates the stacked units, emphasising the double build-up of wall and floor slabs and the gap inbetween units to locate the flexible sound barriers. Due to the structural performance, no additional bracing of the building block is required. The lifting of an apartment module during assembly is shown in Figure 4 c. For on-site works, heavy-duty equipment to manoeuvre the 45 ton units is required.

Mechanical and technical supply systems are preinstalled on defined routes and connected to the main installations on-site.

The construction method enables rapid on-site assembly, enhanced cost and time management, the reduction of risk and noise, and controlled waste management. Furthermore, disassembly of the modules does not require demolition. The system permits building relocations with minimal effort and guarantees for easy modernisation or modifications of cells. However, the weight of the container-shaped units varies between 25 and 45 tons depending on dimensions and size. [4] Constraints due to transport and logistics need to be considered.

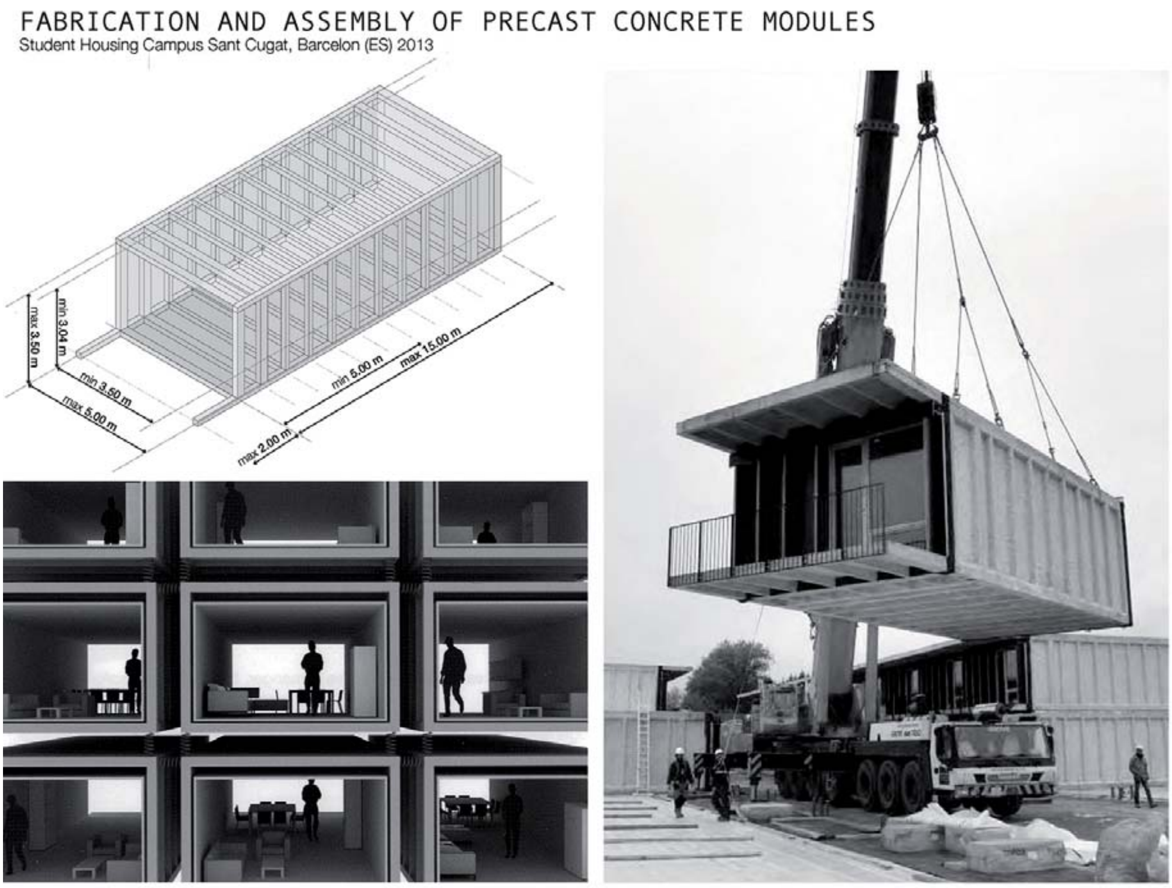

Fig 4 a – b Structural Corpus of Concrete Modules, Fig 4 c Assembly of Apartment Unit

3.2.3 Summary

Due to the double built-up of wall and floor components, the modular concrete system provides excellent insulation values allowing for energy certification ‘A’ for buildings. Depending on materialisation and built-up, an acoustical insulation of 55 dB for walls and 56 to 57 dB for floors and ceilings can be achieved. Furthermore, U-values for thermal transmittance of the building envelope are at 0.30 W/m^{2}K and range between 0.22 W/m^{2}K and 0.30 W/m^{2}K for roofs depending on configuration and material use. Contributing to its life cycle balance, construction process and building operation allow for energy savings and a reduction of CO_2. Compared to conventionally built architectures, savings of up to 60 % are expected. [5]
However, for a comprehensive life cycle analysis, logistical dependencies and transport distances between off-site manufacture and building site play a major role and need to be considered.

4. Discussion

The best practice examples prove the economical and ecological improvement of construction through prefabrication. For both projects, significant cost and time effective advantages were achieved, playing a major role for the developer’s estimations. Material dependencies and regional preferences influenced the choice of building system opposite modular wood or concrete. In both cases, the familiarity with selected materials and systems prevailed.

Current processing methods and engineering technologies allow for improved durability of wood and its high performance as structural component. On the one hand, glue and cross laminated systems enable advanced structural solutions. Especially in the field of high-rise buildings, innovative structural technologies allow for energy efficient material use contributing to reducing the embodied carbon footprint. [6] On the other hand, for the development of intra-urban high-rise structures, however, fire-safety regulations and resulting constraints need to be considered.
A comprehensive design approach to solve material shortcomings is the use of hybrid-components, i. e. wood composites.

Considering the material’s life cycle, concrete requires enormous amounts of energy for production and processing. Emissions make 85 to 90 % of the material’s primary energy consumption and contribute significantly to an increase of the GWP values. Furthermore, the amount of rebar in reinforced concrete affects energy values and ecological properties. For a resource efficient manufacture of the material, the use of rain- and grey water, recycled granulates and break-off materials become eminently important. Additionally, high-performance concrete composites allow for innovative structural solutions, raising its applicability for resource efficient construction.

5. Conclusion and Outlook

5.1.1 Comparison of Methods

The coherence of materiality and building structure remains significant for the valid evaluation of current construction methods. The optimisation of buildings regarding fabrication process and structural systems requires an integrative approach to architectural design. The interrelation of building systems, technologies, and functional and environmental aspects is significant to define valid statements for the development of progressive architectures.

The modular design approaches enable high efficiency of production and assembly, and lead to significant time and cost savings. Controlled operations and monitoring of workflows contribute to to increased security on site, and at the same time reduce waste and water consumption. Finally, the modular structures enable easy exchange and removal of individual components; thus straightforward restoration and changes regarding future building modernization are provided.

Due to shifting the majority of processes from the construction site into the production hall environment, time and cost savings are achieved. Compared with the conventional construction in-situ concrete or masonry savings of up to 60% are expected. As a consequence, the overall energetic optimization of processes is provided.

Yet, the comprehensive assessment requires consideration of the structural materials, significantly influencing a building's ecological performance and technical properties. Compared to the use of wood products, concrete affects the primary energy balance, and leads to substantial limitations regarding the weight of the modules. Depending on size and dimensions, the units weigh up to 45 tons, requiring heavy-duty transport and special equipment for on site works. Ranging between 5 to 6 tons, the timber modules facilitate assembly and installation procedures, as well as transport and logistics.

5.1.2 Capacities of Building Systems

Representing novel manufacture and assembly processes, the above examination demonstrates material shortcomings due to single or mono material use. Hybrid solutions, e. g. wood-concrete composites, widen the fields of application, enhancing the performance of elements. Thus, contributing to an increase of ecological, technical and economical aspects, improved flexibility to today's manifold and diverse building requirements can be provided.
On the other hand, the combination of materials into composite elements affects later material separation, decreasing the recyclability potential. Furthermore, the correlation of varying properties needs to be considered, causing behavioral discrepancies.

6. Acknowledgements

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Innovative building technologies and technical equipment towards sustainable construction – a comparative LCA and LCC assessment

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Summary

Sustainability assessments of buildings have become more and more common. They include the assessment of environmental and economic performance. However, the influence of construction technologies and their technical building equipment as well as the way in which they vary depending on different energetic standards have not been described systematically in literature. For this reason, we evaluated the influence of these aspects and the impact on the environmental and economic performance of residential buildings.
The life cycle performance of 45 variants of a residential building was evaluated by applying the methodology of life cycle assessment (LCA) and life cycle costing (LCC) using quantitative assessment indicators proposed by the current European framework (EN 15643). The variants consist of four main construction types (brick, concrete, wood-chip concrete and prefab timber wood construction) in combination with different energetic standards (low to plus energy) and different technical building systems (pellets, heat pump, solar heating and photovoltaic). This led to a model that displays the existing technical variety.
The comprehensive results show a high optimisation potential for the life cycle performance of buildings in general. However, variation of the technical building equipment and energy standards lead to a higher improvement potential then the use of different construction techniques. Results also indicate that the use of a plus energy standard does not prove to be optimal in all cases.

Keywords: Innovative building technologies, LCA, LCC, construction technology, technical building equipment

1. Introduction

The building sector is responsible for approximately 40% of primary energy and about 24% of greenhouse emissions, both in Europe [21] and globally [25]. Therefore, the international energy agency (IEA) and the European Commission (EC) aim to achieve an 80% reduction of global emissions by 2050. In order to mitigate energy consumption in the building sector, several regulations and directives have been implemented on a European and country level [13]. On a European level, specific measures to reduce energy demand have been introduced with the Energy Performance of Building Directive (EPBD) in 2002 [17] and its recast in 2010 [19]. This EPBD, the Energy Efficiency Directive (EED) [20] and the Renewable Energy Directive (RED) [18] are designed as a package of measures that create the conditions for significant, long term improvements in the energy performance of buildings[15].

In the past, many articles were published on the energy performance optimisation of buildings [14], [22], [23], [26], [36–38]. However, there is now a clear trend of investing in the design of more energy-efficient buildings, and paying more attention to the embodied energy and related embodied impacts of such building concepts, taking the whole life cycle into consideration (e.g. the activities of IEX Annex 57[1]). The recently published European framework for the sustainability assessment [9–12] provides a clear guideline on how to assess and report the environmental impacts in a transparent way. According to this framework, the building is to be assessed based on a functional and technical equivalent and the environmental assessment is to be based on the methods of Life Cycle Assessment (LCA, [1], [2]).

In the current literature on LCA on buildings (e.g. [6], [22], [27], [28], [31], [39], [40]), a cross building related assessment of different energy standards and the influence of technical and/or different construction materials can hardly be found [16], [29], [32].

There is also no systematic description of the influence of construction technologies and technical building equipment on the variation of different energetic standards (e.g. low energy, nearly zero energy or plus energy). For this reason, we evaluated the influence of these aspects and the impact on the environmental and economic performance in the case of a single-family house, which served as case study.

2. Methodology

The aim of the paper is to analyse the economic and environmental performance of the case study using the methods of Life Cycle Assessment (LCA) and Life Cycle Costing (LCC). These methods are used to quantify the difference in design options by using different construction materials, different energy systems and different energy standards. The whole variety of different combinations shows 45 scenarios, which were evaluated on their life cycle performance. The assessed scenarios consist of four main construction types (brick, concrete, wood-chip concrete and prefabricated timber wood construction) in combination with different energetic standards (low to plus energy) as well as different technical building systems (pellets, heat pump, solar heating and photovoltaic). The LCA and LCC analyses show which parts of the building are responsible for the main environmental and economic impacts.

2.2 Description of the Case Study

Different design options were created using a real single family house project [30], [35]. The case study is a two-storey building with a gross floor area of 220sqm (ground floor and first floor). Figure 1 shows the floor plans and cross section.

1 http://www.annex57.org

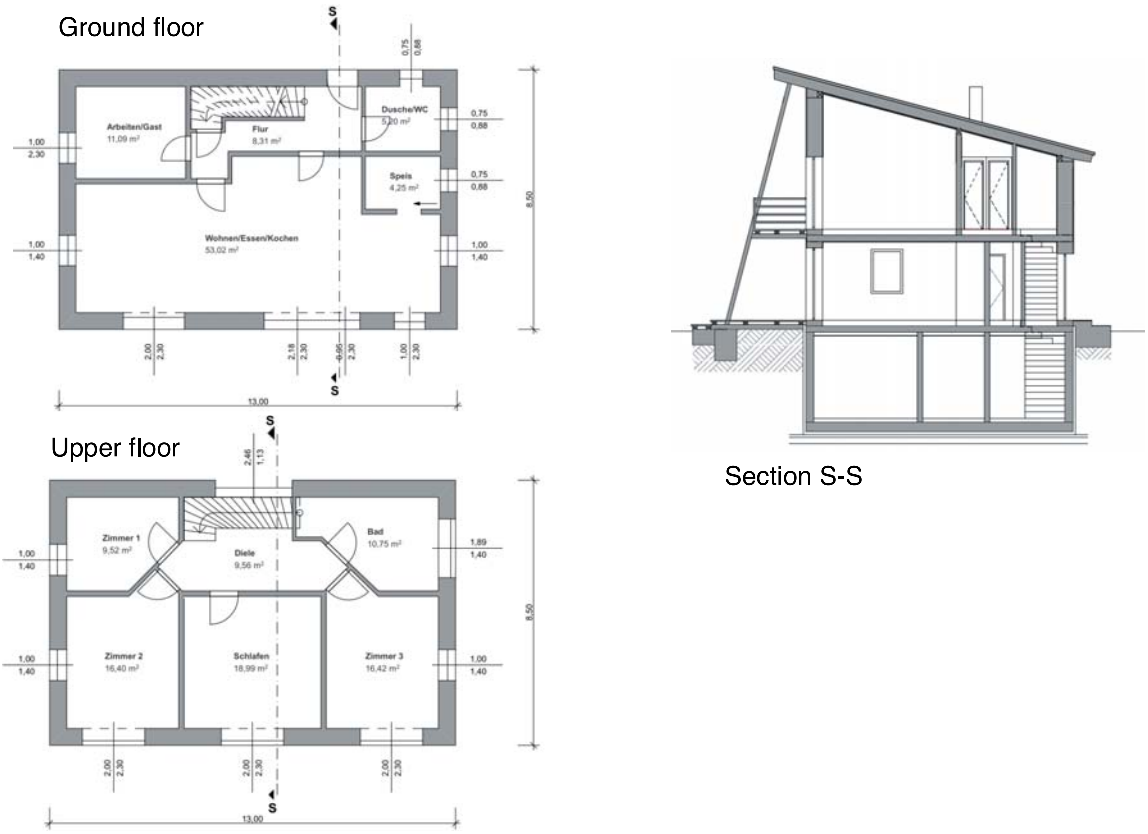

Fig. 1: Floor plans and cross section of the case study

This building design is the basis for all different scenarios. Within all the scenarios, the external dimensions and the cellar were kept the same. This means that the gross floor area depends on the wall thickness (reduced area), which is limited by the Austrian building code and therefore needs to stay the same. For these design targets, different construction materials and different insulation materials were used to model and calculate the energy demands according to Austrian standards. The energy demand of the different buildings has been calculated using certified energy performance software. For brick and wood chip concrete constructions, two scenarios, which do not need insulation materials to fulfil the low-energy standard, were assessed additionally. Table 1 shows the materials that were used to model the different building scenarios.
As a first step, different energy standards were defined from a heating demand perspective based on ÖNORM H 5055 [4], according to which the different design options should be a “low-energy” building with a heating demand of about 40 [kWh/m2a] (code L and S) and a “passive-house” building with a heating demand of about 10 [kWh/m2a] (code P and E - see Table 2).

Table 1: Construction materials and insulation materials with codes

		Insulation type with symbol			
Construction material	Symb.	EPS	Rock wool insulation	Wood-fibre insulation	Without additional insulation
Bricks	**B**	**E**			**1**
Concrete	**C**	**E**			
mantle block (wood-concrete)	**M**	**E**		**W**	**1**
Wood solid	**Ws**		**R**		
Wood-frame construction	**Wf**		**R**		

The various technical systems for the different energy standards are shown in Table 2. The heat pump, pellet boiler, solar thermal panels, single item wood furnace and photovoltaic (PV) in the scenarios were evaluated for the different energy standards (see table 2). Additionally, a "sun-house" concept was analysed. In this concept, solar thermal collectors provide at least 50 % of the heating energy needed.

Table 2: Technical systems

	Low-energy standard			Passive-house standard		
	40 [kWh/m^{2}a] HWB_{ref}			10 [kWh/m^{2}a] HWB_{ref}		
Technical system	x-L-x-H	x-L-x-P	x-S-x-Si	x-P-x-H	x-P-x-P	x-E-x-H
Pellet boiler		Pellet boiler 10 kW	Single item (logs) 25 kW		Pellet boiler 10 kW	
Heat pump	Ground-water 10 kW_{th}			Compact unit Air-Air 1.8 kW		Compact unit Air-Air 1.8 kW
Solar thermal panels			Panel area 45 m²			Panel area 10 m^2
PV panels						61 m^2 PV panels, 6 kWp
Floor heating	yes	yes	yes		yes	
Additive system (backup)				Electric radiator 6 units		Electric radiator 6 units
Mechanical ventilation incl. heat-recovery				yes	yes	yes
Storage system (heating and hot water)	170 l Buffer storage	1000 l Heating storage 200 l WW-storage	7000 l Heating storage 300 l WW-storage	200 l Buffer storage	1000l Heating storage 200 l WW-storage	500 l WW-storage

The different construction and insulation materials were then combined with the technical systems in a scenarios matrix to a total scenario set of 45 variants. For the presentation of the results, codes for the different scenarios are used to identify the different measures. The first digit represents the construction material (code B, C, M, Ws, Wf; see table 1), the second the energy standard (code L, S, P, E; see table 2), the third the insulation type (code E, R, W, 1; see table 1); and the fourth the technical system (code H, P, Si; see table 2).

2.1 Environmental performance - LCA

The calculations of the environmental performance of the different scenarios are based on EN 15978 [11] and ISO 14040/14044 [7], [8]. The different scenarios have been assessed by the use of LCA for the whole life cycle, pictured in table 4. The materials for the different construction techniques were quantified and modelled for the modules A1 – A3.

For the reference study period of 100 years, the different replacement scenarios (module B4) were assessed based on an expert survey. Furthermore, the end of life stage (C3 – C4) was modelled on the basis of the expert survey (disposal, incineration, recycling, etc.) for the various materials.

The results from the energy simulation performed according to Austrian standards were used to quantify the operational energy use (B6). For the life cycle impact assessment (LCIA), the ecoinvent database v2.2 [24] was used to quantify the environmental performance.

Table 4: Life cycle stages

Balanced stages of life cycle of the building																
A 1-3 Product stage			A 4-5 Construction process stage		B 1-7 Use stage							C 1-4 End of life stage				
A1 Raw material procurement	A2 Transport	A3 Production	A4 Transport	A5 Construction	B1 Use stage	B2 Maintenance	B3 Repair	B4 Replacement	B5 Refurbishment	B6 Operational Energy use	B7 Operational Water use	C1 Deconstruction	C2 Transport	C3 Waste pro-cessing	C4 Disposal

The assessment for the environmental performance was carried out for the indicators, which are described in table 5.

Table 5: Environmental indicators

Symbol	Indicator	Unit
AP	Acidification potential on soil and water	kg $(SO_2)^{2-}$ eq /m²a
EP	Eutrophication potential	kg $(PO_4)^{3-}$ eq /m²a
ODP	Ozone depletion potential	kg CFC-11 eq /m²a
POCP	Photochemical oxidants creation potential	kg C_2H_4 eq /m²a
GWP	Global warming potential	kg CO_2 eq /m²a
CED non ren	Cumulative energy demand non renewable	MJ /m²a
CED ren	Cumulative energy demand renewable	MJ /m²a

2.2 Economic performance - LCC

The calculation of the economic performance is based on a detailed calculation of the initial construction costs according to ÖNORM B 1801-1 and 1801-2 [3], [5] for the same life cycle stages as pictured in table 4 with the same system boundaries, as used for the calculation of the environmental performance.

Table 6 gives an overview of the relevant calculation parameters for the life cycle costing (LCC) based on the Austrian sustainable building council (ÖGNI), which refers to the German DGNB/BNB [33], [34], for a reference study period of 50 years.

Table 6: Calculation parameters for LCC

Electricity price	0,17 €/kWh
Pellets price	0,25 €/kg
Wood price	0,16 €/kg
Discount rate	5,5 %
Inflation rate	2,0 %
Escalation rate	4,0 %

3. Results and Discussion

3.1 Environmental performance

The results of the environmental performance are shown in figures 2a and 2b. Due to the limitations of the paper, only the results for GWP and CED n.r. are presented. The different life cycle stages (A1-A3, B4, B6 and C3-4) are highlighted in different colours, to illustrate the difference between the phases. Negative environmental impacts are only pictured for the scenarios in plus-energy standard (Code x-E-x-x) due to the energy production onsite. The results also show the significant difference between the embodied and operational impacts in the different scenarios

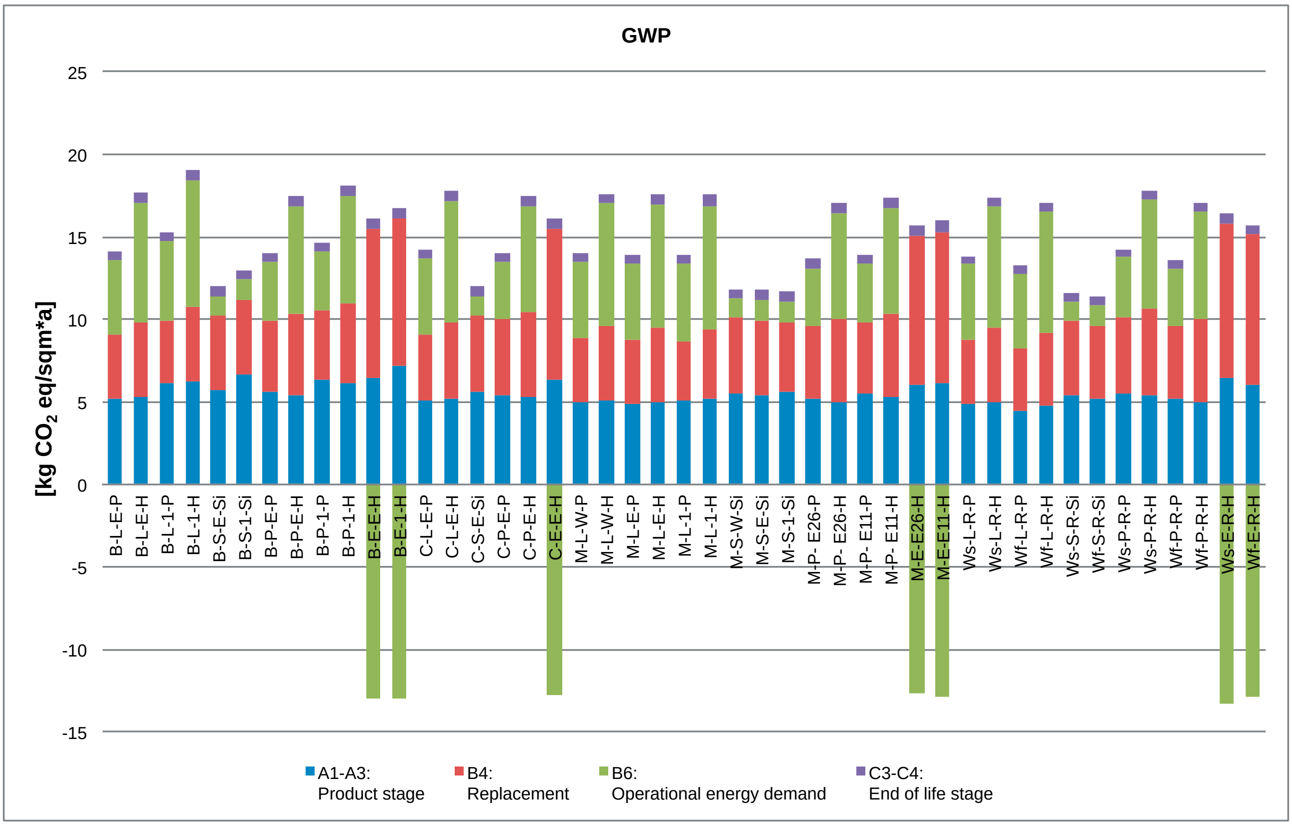

Fig. 2a Global Warming Potential [kg CO2/m2a]

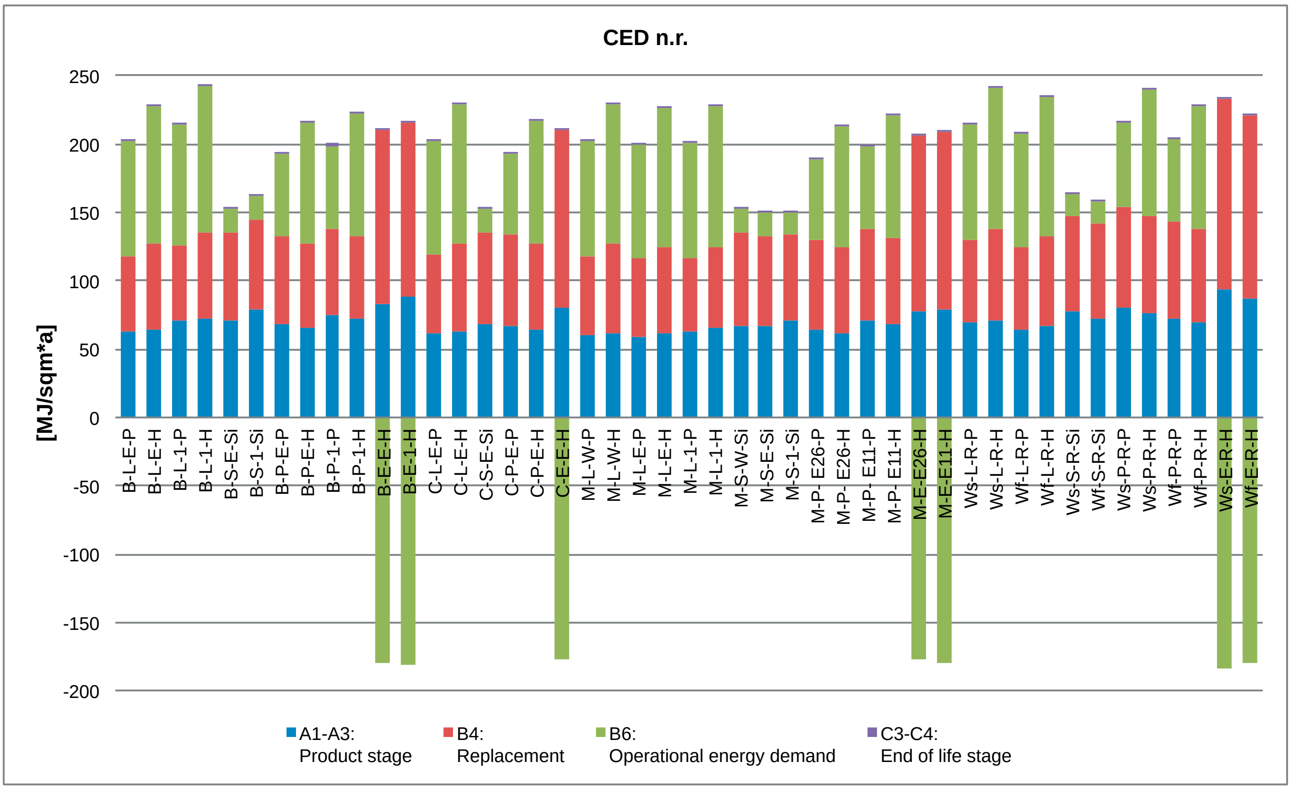

Fig. 2b Cumulative Energy Demand non-renewable [MJ /m2a]

For the CEDn.r., the same trends apply as for the results of GWP. Due to the major influence on the energy systems, a more detailed analysis for all environmental impacts is shown in figure 3.

3.2 Technical system

The results of the environmental performance show a big spread of the different energy systems. For these systems, the operational energy use (B6) dominates the environmental impacts and differs according to the chosen energy carrier. However, the assessed indicators do not indicate a clear preference for a single technical system as some environmental indicators run counter. Therefore, the authors recommend evaluating the aspect of primary energy factors and LCA allocation rules for delivered and exported energy in detail, especially in the case of the plus energy concept. Especially in the case of heat pump systems, the results on ODP are caused by the cooling refrigerants.

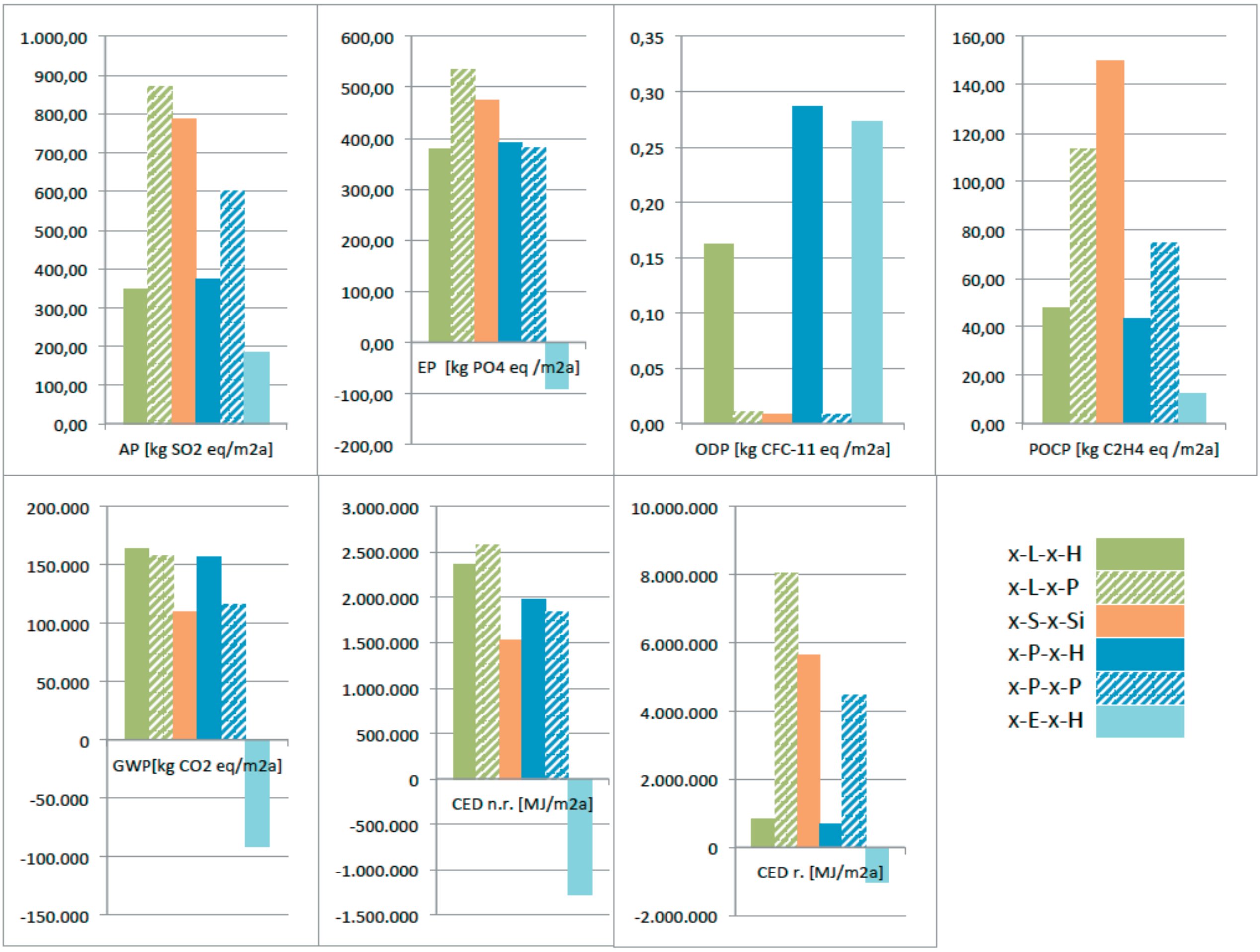

Figure 3: Results for the technical systems over the whole life cycle

3.3 Economic performance

The results of the economic performance based on the LCC calculations are presented in figure 4, which shows the total net present value per sqm. gross floor area. It can be observed that the life cycle costs of the different construction techniques and technical systems are rather similar. However, the results also indicate that construction costs are very dominant when calculated based on a high discount rate (i.e. 5.5%) combined with low energy costs. Due to this fact, the results show that the additional investment and related replacement costs for better energy standards and energy performance hardly pays off over a life time of 50 years.

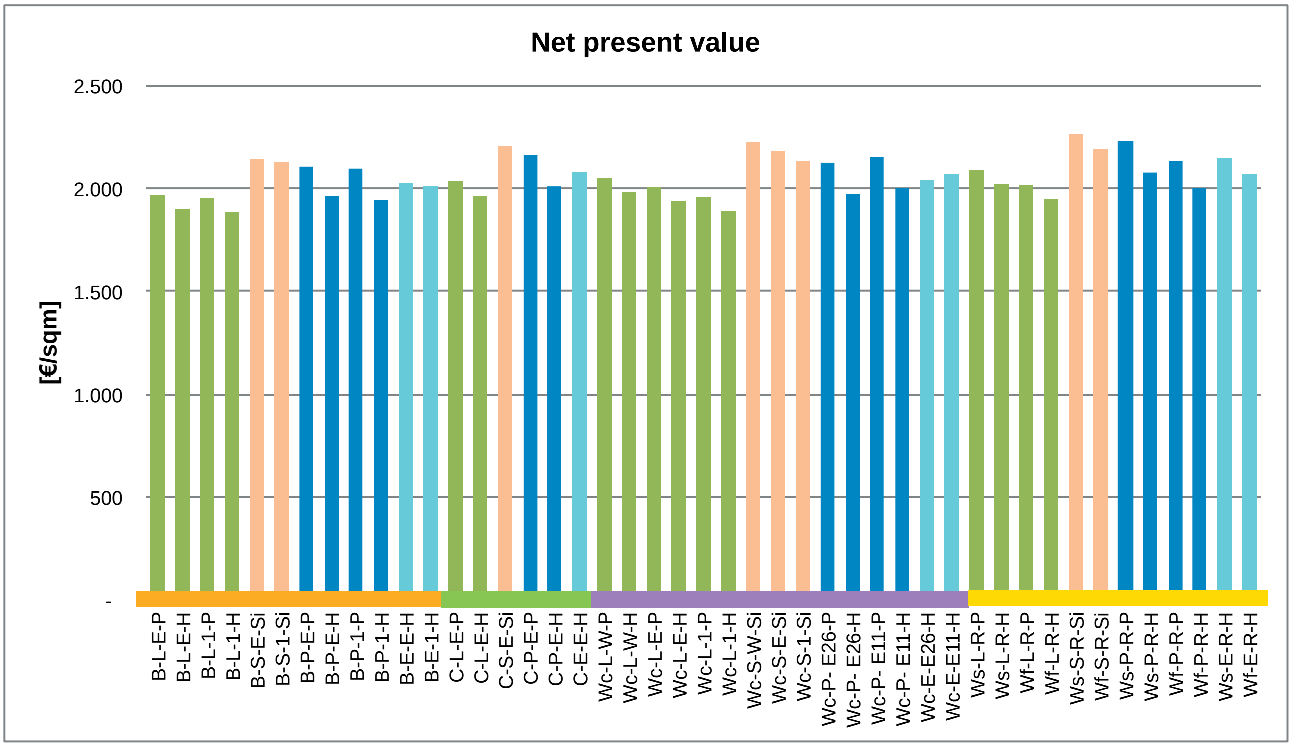

Figure 4 Net present value

4. Conclusion

The comprehensive results show a high optimisation potential for the life cycle performance of buildings in general. The results indicate that the choice of different construction technologies and building materials does not lead to as high an improvement potential as the variation of the technical building equipment and the energy standard. However, in every case the results show an increasing importance of material related embodied impacts. Due to the current trend towards more and more energy efficient buildings, the role of materials within environmental assessments will increase dramatically and should therefore be researched more precisely.

In the case of the plus energy buildings, the authors recommend evaluating the aspect of primary energy factors and LCA allocation rules for delivered and exported energy in detail, as the results of the environmental performance can change with different scenarios.

Regarding the sensitivity analysis of the results of the environmental and economic performance, the authors do not agree with the definition of the functional unit on a gross floor area, which is standardised for economic calculations, as the results differ with highly insulated buildings due to the increase in wall thickness. This fact should be evaluated in more detail.

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Institutional conditions for sustainable private sector-led urban development projects: A conceptual model

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Summary

Across the globe sustainable private sector-led urban development projects (SPUDPs) in the built environment rarely commence as real estate developers face several institutional barriers which limit their capacity to develop economic-viable, social-responsible, environmental-friendly urban places. Hence, SPUDPs are a promising development strategy for cities as the scale of such projects could be an effective means to integrate public planning policies and private development decisions with a broader social impact as opposed to solely developing sustainable buildings. However, it is largely unknown how SPUDPs can be effectuated as insight is lacking into institutional conditions that could incentivise real estate developers to make decisions for sustainable urban development practices. This paper explores the institutional conditions, in particular the policy instruments from local planning authorities, that nudge private decision-making to realise SPUDPs, by means of a literature review resulting in a conceptual model. The paper reveals that developers can be incentivised by pro-active local planning bodies using a combination of planning policy instruments which foster a sustainability-sensitive market decision-making environment.

Keywords: sustainable urban development projects, institutional conditions, real estate developers, local planning authorities, market decisions

1. Introduction

Sustainable development has generated wide attention among scholars in the academic domains of spatial planning (e.g. Dempsey *et al.*, 2012; Rydin, 2010; Pearson *et al.*, 2014) and real estate (e.g. Christensen, 2012; Reed & Sims, 2015; Wilkinson *et al.*, 2015). However, limited academic attention has been paid to sustainability at the intermediate operational level of urban development projects (UDPs). UDPs consist of redeveloping land into mixed-use inner-city areas in which public, private and civil interests materialise through a complex process of actor (inter)actions. Often UDPs are characterised by integrative development strategies which hold the potential of creating successful places as various objectives of different stakeholders are incorporated in the decision-making process. Sustainable urban development projects (SUDPs) aim to realise economic-viable, social-responsible and environment-friendly urban places. They hold great potential to meet some socio-environmental challenges faced in cities. Foremost, the cumulative development of various these projects could be an effective means to gradually implement a multitude of sustainable planning policies within cities, thereby closing the policy-implementation gap (Heurkens *et al.*, 2015). In addition, the focus on creating mixed-use urban places probably has broader social impacts than focusing only on constructing sustainable buildings (Williams & Dair, 2007) as SUDPs require substantial local community involvement, and hold the 'economy of scale' potential for integrating eco-solutions (Rydin, 2010). However, Dixon (2007: 2380) argues "there has also been little detailed research to examine how the property development industry, as one of the key actors and stakeholders in [urban development], is responding to [sustainable development policy] concepts 'on the ground', through specific, local-area-based [urban development] initiatives." In this regard, private sector-led urban development projects (PUDPs) (Heurkens, 2012; Heurkens & Hobma, 2014) have come forward as potential strategy to develop local sustainable initiatives. Such projects are considered as a form of public-private partnerships in which real estate developers play a leading role in designing, financing, developing and managing urban projects, and local planning authorities adopt a facilitating role to support such private initiatives (Heurkens *et al*., 2015). PUDPs symbolize the changing public and private roles and relations in urban planning, with shifts towards forms of private planning (Andersson & Moroni, 2014; Hackworth, 2007). This situation requires local planning authorities to crucially influencing market decisions by deploying a variety of planning policy instruments (Adams & Tiesdell, 2010; 2013).

The promise of urban development projects as an appropriate scale for sustainable policy implementation and the shift towards more private sector involvement in city development, illustrate the importance of understanding how real estate developers can be incentivised by planning authorities to develop SPUDPs. Critics argue that it is highly questionable if private organisations with their traditional profit-maximisation decision-making rationales (e.g. Henderson, 2010) can deliver SPUDPs. Nonetheless, urban practices across the globe indicate that private organisations increasingly adopt social and environmental concerns in their development, investment and partnership decisions and strategies as evidence from recent studies indicate (e.g. Potters & Heurkens, 2015; Sturm *et al.*, 2014). This awareness is reflected in private sector policies based on principles such as corporate social responsibility (CSR) (Reed & Sims, 2015) and socially responsible property investment (SRPI) (Squires & Moate, 2012), and the presence of 'market-driven' environmental assessment methods like BREEAM, LEED, Green Star and other rating tools.

2. Methodology

Despite the ample opportunities for developing sustainable urban places, it remains largely unknown which institutional conditions support market decisions to develop sustainable private sector-led urban development projects (SPUDPs). This poses questions about how SPUDPs can be effectively delivered by setting the 'right' institutional conditions for market actors. Therefore, the main question this paper addresses is: *Which institutional condtions for delivering sustainable private sector-led urban development projects can be identified by linking planning policy instruments to market decisions?* The aim of the paper is 1) to identify potential institutional barriers and incentives for developers to make decisions about developing sustainable urban projects and 2) to construct a conceptual model which aligns planning policy instruments to market decisions. Therewith, the paper enables key stakeholders to effectively align sustainable urban policies with development decisions. In order to answer this question the paper contains a literature review on institutional barriers and incentives found in real estate and urban planning publications. Based on these findings a conceptual institutional model is constructed which relates planning policies to market decisions offering opportunities for academics and practitioners to set the 'right' institutional conditions for delivering sustainable urban development projects.

3. Results

The results presented hereinafter are based on a literature review. In section 3.1 we describe the importance of understanding institutions for our paper, followed by preliminary findings on barriers and incentives for sustainable urban development. Section 3.3 sets out how public planners can use policy instruments to influence market actors to make sustainable development decisions, ultimately resulting in a conceptual model for delivering SPUDPs in section 3.4.

3.1 Institutional conditions

It is relevant to understand the institutional context of urban and real estate development processes. Buitelaar *et al.* (2014: 249) claim that "institutions are commonly defined as the man-made structures that guide and give meaning to human interaction." Institutions are not given social products that are actively created and changed through action. There is reciprocity between institutions and actors; institutions affect actors' actions, and actors actively shape institutions. Also, institutions can be formal and informal in nature. Buitelaar *et al.* (2014: 249) define formal institutions as "government rules that are enforced by the legal system, such as laws, constitutions, ordinances and local land-use plans." Informal institutions are less explicit rules of conventions, codes of behaviour, traditions and values. In essence, institutions are the 'rules of the game' which influence decision-making by actors to a large extent and are cultivated through actor interactions (Van Bueren & Ten Heuvelhof, 2005). Therefore "urban development is [also] the product of the interaction between actors and institutions" (Buitelaar *et al.*, 2014: 250). In this paper, institutional conditions then refer to formal and informal institutions – more specifically actor instruments and interactions – that influence policy-making and decision-making.

3.2 Barriers and incentives for sustainable urban development projects

Barriers and incentives for market actors to develop sustainably are applicable to various levels and aspects. Rydin (2010) argues that sustainable urban development is concerned with the scale of the building, development site, and urban area. This paper focuses on urban development sites, or what is often called urban places (Adams & Tiesdell, 2013), urban regeneration or development projects (UDPs) (Heurkens, 2012). It is important to understand that at this level governing a multitude of sustainability issues takes place through a constant interaction between public and private organisations. In that sense, UDPs can be regarded as effective means to implement (often public) planning policies (Heurkens *et al.*, 2015) and in particular those including principles of sustainable cities (Pearson *et al.*, 2014). Therefore, sustainable urban development projects (SUDPs) are an appropriate unit of analysis to understand public-private interaction and policy implementation. What do we mean with SUDPs? In our view these projects aim to realise economic-viable, social-responsible, environmental-friendly urban places within inner-cities. The biggest challenge here is to focus on brownfield redevelopment sites in order to recycle land within the existing built environment, instead of choosing for 'unsustainable' greenfield sites. Dair & Williams (2006) indicate that central to this choice lays the concept of urban compaction. "Proponents of the compact city argue that high-density, mixed-use living enhances sustainability because it reduces car use and pollution, leads to urban vitality and vibrancy, encourages social interaction, and provides support for local economy and facilities" (Dair & Williams, 2006: 1345). Dempsey *et al.* (2012) add that it involves well-connected urban lay-outs and easily accessible transport networks. In this respect, Raco & Henderson (2006: 499) state that "bringing brownfields back into use tends to be, a priori, presented a 'good thing' that will have broader economic, environmental and social benefits." More specifically, Williams & Dair (2007: 139) introduce a conceptual model for sustainability objectives to be met in brownfield developments (see Table 1). We follow this view when we adhere to SUDPs as objectives are policy-driven and less rigorous than concrete physical solutions.

Table 1: Sustainable categories and objectives of UDPs (based on: Williams & Dair, 2007: 139)

Sustainability category of UDPs	Sustainability objectives in UDPs
Economic sustainability objectives	Economic-viable UDPs
	To enable businesses to be efficient and competitive
	To support local economic diversity
	To provide employment opportunities
Social sustainability objectives	Social-responsible UDPs
	To adhere to ethical trading standards during the development process
	To provide adequate local services and facilities to serve the development
	To provide housing to meet needs
	To integrate the development within the locality
	To provide high quality, liveable developments
	To conserve local culture and heritage, if appropriate
Environmental sustainability objectives	Environment-friendly UDPs
	To minimise the use of resources
	To minimise pollution
	To protect biodiversity and the natural environment

There are explanations for why urban sustainability objectives are difficult to realise. Dair & Williams (2006) distinguish five reasons for variations in the achievement of SUDPs including: stakeholder knowledge of development proposals; timing of stakeholder involvement; absence of power to enforce sustainability; various attitudes of stakeholders towards sustainable technologies; and most fundamental, stakeholders' attitude towards and knowledge of the issue. However, Dair & Williams (2006) also conclude that 'champions' of sustainability were found amongst most stakeholders, including real estate developers. This indicates that sustainability attitudes of the private sector are not necessarily less-supportive than those from public bodies. Nonetheless, Dixon (2006: 237) argues that "despite the increasing focus on sustainability in government policy, the [UK] development industry seems ill at ease with precisely how sustainable development can be implemented in brownfield schemes." This led Dixon (2007: 2382) to claim that there is "clear evidence to suggest that many [UK developers are] simply paying 'lip service' to sustainability. Dixon (2006) highlights a need for better benchmarks to measure sustainable brownfield regeneration, in order to quantify its life cycle cost-benefit ratio. However, solutions are not easily found to alter this situation. Barriers to sustainability implementation of UDPs include infrastructure and governance issues, and can be broadly characterised as being perceptual, institutional and economic (Dixon, 2007). Williams & Dair (2007), in a study of identifying the barriers of sustainable building in England, conclude that the following barriers where commonly recorded: non-consideration of sustainability by stakeholders; non-requirement of sustainability by client; no power to enforce sustainability; replacement by another sustainability measure; restriction/non-allowance of sustainability by regulators; high costs of sustainability measure; non-compliant site conditions for sustainability; inadequate, untested, unreliable sustainable materials/products; and non-availability of sustainability measures. Such barriers can be labelled as lack of demand, lack of knowledge, lack of power, high perceived costs, ineffective regulation, location characteristics, and lack of expertise. Despite this, Rydin (2010) argues that SUDPs offer the necessary economies of scale to integrate various sustainability objectives such as carbon reduction, water efficiency, waste management, nature conservation, and climate change adaptation. This might manifest itself in the physical requirements aimed at the delivery of sustainable buildings, infrastructure, food, water and energy systems that strengthen social networks and create opportunities for a strong local economy (Wiseman *et al*., 2014). Wiseman *et al.* (2014) further point out that there are four key pathways to sustainable resilient cities including: imaginative integrated visions and plans; cross-sectoral partnerships; and effective policy instruments, which are important conditions for accelerating innovation. Complementary to this, according to Raco & Henderson (2006: 499), achieving wider benefits from SUDPs requires a “more comprehensive set of development projects and policy agendas”. To put it into other words, this is a pledge for a closer alignment of development and policies, or private and public interests. Hence, from a real estate market perspective these pathways only assort effect and become institutional incentives (and not barriers) once aligned with private developer decision-making rationales.

3.3 Planning policy instruments and market decisions

In this regard, Adams & Tiesdell (2013) developed a categorisation of planning policy instruments that effectively adhere to market decision-making based on the notion of ‘planners as market actors’. In order to develop successful urban places Adams & Tiesdell (2013) argue that planners should operate as actors within rather than outside markets. They can do this by deploying policy instruments that shape, regulate, stimulate, and build the capacity to influence market decisions. Shaping instruments include non-statutory plans and visions which guide market decisions. Regulatory tools include rules and laws which condition market decisions. Stimulus instruments consist of financial-fiscal incentives to lever market investment. And capacity building involves market-rooted networks and relevant skills which change market decisions and behaviours. Heurkens *et al.* (2015) further argue that such policy instruments should be tightly coupled with planning actions to enable implementation. Therefore, a certain degree of instrument flexibility is needed to respond to changing market needs and specific local circumstances. Hereinafter, we discuss some (sustainable) policy instruments and examples and how they might affect market decisions.

3.3.1 Shaping instruments

Municipal sustainable city visions, localised sustainable urban development plans, and sustainability assessment instruments, give direction for real estate developers to develop sustainable places. According to Berke & Conroy (2000) localised plans should embrace liveable built environment principles with for instance physical space requirements including the location, shape, density, mix, proportion and quality of urban development. In addition, Carter *et al.* (2015) argue that comprehensive sustainable design and programmes is a prerequisite for the implementation of plans, such as Rotterdam’s Climate Proof adaptation programme (City of Rotterdam, 2010). Also key performance indicators (KPIs) for sustainable urban development as promoted by Christensen (2012) could be beneficial. However, government-led plans seldom are effectively implemented by developers, as often planning systems in which they are embedded do not sufficiently incorporate market needs. Planners should be aware that shaping market decisions to develop sustainable places through formulating plans requires public-private interaction. For instance, despite the direction these instruments give to markets, we notice that private companies– like multinational Siemens with its Green City Index (Siemens, 2012) and developer/investor Grosvenor with its Resilient Cities Index (Grosvenor, 2013) – themselves initiate assessment tools for sustainable urban development investment opportunities. Other examples of market-driven voluntary assessment methods – some of which are focusing on urban areas like the BREEAM Communities and LEED-ND framework – also point out that the development industry is using such frameworks based on market reasons. If such frameworks are important to the industry, we would expect shaping planning policies to contain information about prioritised development sites that could possibly accommodate sustainable private urban development investments. This challenge can be met by obtaining information on sustainability decisions from market actors, currently insufficiently understood especially at the neighbourhood level (e.g. Sullivan *et al.*, 2014).

3.3.2 Regulating instruments

In addition to shaping instruments, regulating policies can often be effective tools to mitigate unwanted or unsustainable environmental-social consequences of development. Williams & Dair (2007) argue that private stakeholders involved in development and construction show a *lack of awareness* in building sustainable developments, and state that public bodies should be enforced to apply regulations which are more stringent to achieve sustainable urban developments. Regulation of markets is necessary as “conventional market mechanisms provide limited applications for designing sustainable communities, because markets often fail to produce economically optimal and socially desirable outcomes” (Hendrickson *et al.*, 2011: 161). As such, regulatory power is regarded as a planning policy tool which is mandatory for developers to comply with through development proposals and planning application procedures, in order to seek planning permission or building permits. Importantly, Adams & Tiesdell (2013) emphasise that such regulatory tools also serve as creating some sort of certainty for market actors as they reduce procedural and political risks. Hendricksen *et al.* (2011: 159) identify several regulatory instruments that might create more sustainable outcomes including: standards, certifications, controls, restrictions; permits and licenses. For instance changing building codes and zoning standards to support sustainable outcomes, linking planning applications and development approval processes to sustainable objectives, and creating non-financial incentives for sustainable behaviour, might prove effective in enabling SPUDPs. Also, at state level, there are possibilities to influence market decisions such as state law or mandates (Berke & Conroy, 2000). These have an effect on the development industry as a whole and structure local public-private decision-making. For instance, in the Netherlands the ‘Ladder for Sustainable Urbanisation’ (I&M, 2013) is a national government law propagating brownfield redevelopment that tests land-use plans from decentral governments. This implies that public land-use plans indirectly nudge private decision-making to focus development towards inner-cities. In addition, private law in the form of tenders and development agreements, offers opportunities for planning bodies to require developers to submit sustainable plans.

3.3.3 Stimulating instruments

Adams & Tiesdell (2013) illustrate that stimulating planning policy tools include: direct state actions, price-adjusting instruments; risk-reducing instruments, and capital-raising instruments. In this regard, Hendrickson *et al.* (2011) point out that these are mainly financial instruments that would convince developers to invest in SUDPs, which might include: charges and pricing; taxes and tax exemptions; loans, grants and funding; and direct incentives and subsidies. They portray that deploying such instruments would make sustainable urban development investments more accountable, beneficial, generate private equity, generate revenues, stimulate innovation and technology research, diversify investment options, reduce perverse incentives and subsidies, and discourage unsustainable behaviour. For instance, promoting socially responsible investment funds in combination with an additional development grant, might give the necessary financial threshold for real estate developers and investors to decide to invest in and deliver SUDPs (see Christensen, 2012). Specifically, Jollands (2014: 160) argues that “stimulating investment in sustainable and resilient urban energy systems should be straightforward, at least in theory.” However, the benefits of such systems are often ‘invisible’ and difficult to quantify. Moreover, several pervasive barriers for investment remain (Jollands, 2014: 161) in relation to such systems, like: lack of information about benefits; perceived risks and lack of certainty associated with returns and benefits; low priority people give to energy cost reduction; energy prices not reflecting externalities; and principal-agent problems. Furthermore, most of these barriers relate to energy issues that are not necessarily the expertise and the primary concern of real estate developers, but more applicable to private energy service companies. To stimulate private investment in sustainable energy systems private-private partnerships between developers and energy service companies might be necessary to pull resources and expertise, and share risks and benefits. Moreover, public-private partnerships could function as capital-raising risk-reducing instruments for SPUDPs.

3.3.4 Capacity building instruments

All such instruments might prove to be less effective unless local planning authorities enable development actors to operate more effectively (Heurkens, *et al.*, 2015). Capacity building in this respect means developing the capacity to facilitate market decisions. Planners in this respect can influence such decisions by an active attitude through shaping market cultures, mind-sets and ideas; obtaining market-rich information; participating in market-rooted networks; and developing market-relevant skills. This means that for promoting sustainable development all levels of local government should be actively involved (Saha & Henderson, 2011). Moreover, it indicates that leadership from the private sector in delivering sustainable urban development should be complemented by active committed public leaders. In this regard, Pearson *et al.* (2014: 49) argue that "leadership can and should come from all sectors of our cities – mayors, private developers, [and] community." With regard to climate change adaptation, Carter et al. (2015: 6) refers to this as adaptive capacity: "the ability of city governors, businesses and residents, and associated structures and systems to prepare for and moderate potential harm from climate change hazards and exploit any emerging opportunities." In brief, this indicates that governing for sustainable urban development (Rydin, 2010) involves understanding other attitudes and learning from best practices (Bulkeley, 2006) and to construct governance arrangements which incorporate positive incentives for actors to cooperate (Van Bueren & Ten Heuvelhof, 2005). For instance participating in strategic triple helix networks, attending sustainability conferences, and stimulating public-private partnerships for development projects, are important interaction platforms for public planners to understand market logics and make informed policy decisions. Moreover, through such planning-market interactions, planners can restructure and redesign existing shaping, regulating, and stimulating tools to bring them in line with market decisions.

3.4 Conceptual institutional model for sustainable urban development projects

This preliminary literature review reveals that linking private sector decisions to public policy instruments is not an easy task, because there are multiple barriers and incentives operating at different institutional levels. However, here we present a first attempt to develop a conceptual model which can be used to bridge public policies with private decisions to deliver sustainable urban development projects. Table 2 shows the conceptual institutional model for SPUDPs. It illustrates how public planning policy instruments and particular policy tool sub-types and examples can affect market decisions to invest in and develop sustainable urban places. By doing so certain institutional incentives are created to overcome some institutional barriers for real estate development actors to realise SPUDPs. The first three columns derive from Heurkens *et al.* (2015) who applied a similar model to a study of private sector-led urban development projects in the UK. Column three has been modified with specific sustainability tool examples whenever possible and appropriate. The content of the last two columns resonate with the literature findings presented in this paper. The incentives and barriers for delivering SPUDPs identified within the literature review have been simplified and generalised in Table 2 in order to facilitate future testing and application.

Table 2: Conceptual institutional model for sustainable urban development projects

Policy instruments	Impact on market decisions	Sub-types and *examples*	Incentive created	Barrier overcome
Shaping	Shape decision environment of development actors by setting broad context for market actions and transations	Development/investment plans		
		Development/investment priorities	Brownfield development sites	Lack of policy certainty
		Regulatory plans		
		Statutory land-use plans, mandates	Formal sustainable requirements	Lack of commitment
		Indicative plans		
		City sustainability visions, policies	Synchronisation of policies	Lack of imagination/vision
Regulating	Constrain decision environment of development actors by regulating or controlling market actions and transactions	State/public regulation		
		Planning permissions,building permits	Formal sustainable procedures	Lack of consistent rules
		Contractual regulation		
		Tenders, development agreements	Certain development directions	Lack of power/influence
Stimulating	Expand decision environment of development actors by facilitating market actors and transactions	Direct state action		
		Brownfield land acquisitions	Competitive advantages	Lack of market support
		Price-adjusting instruments		
		Taxes, charges, loans, grants, bonuses	Improvement of cost-benefit ratios	Lack of financial benefits
		Risk-reducing instruments		
		Certifications, measurement tools	Investment in certified buildings	Lack of demand/benchmarks
		Capital-raising instruments		
		PPPs, investment funds	Leverage for sustainable investments	Lack of social-eco benefits
Capacity building	Enable development actors to operate more effectively within their decision environment and so facilitate the operation of other policy instruments	Market-shaping cultures		
		Sustainable behaviour subsidies	Increased responsibility/awareness	Lack of responsibility
		Market-rich information		
		Sustainability best practice promotions	Insight in proved practices	Lack of empirical prove
		Market-rooted networks		
		Business/community networks	Increased participation/innovations	Lack of governance
		Market-relevant skills		
		Sustainability education/training	Development of learning skills	Lack of expertise/knowlegde

4. Discussion

What the model reveals is that more conscious linking of public planning policies to private development decisions can potentially generate a variety of incentives and overcome barriers. In theory, conceiving of public planning policy instruments as potential incentives for overcoming the barriers experienced within the real estate development industry's decision-making to realise sustainable urban development projects is quite relevant and new. Therefore, at this point the limitations of this paper are: 1) the possibility of missing out on relevant institutional conditions, and 2) the generalisability of empirical findings for other institutional contexts. It is extremely difficult to cover all institutional conditions for SPUDPs through literature review. Therefore, we aim to validate and complement these institutions with follow-up research. The model can be supplemented by more in-depth literature studies on real estate developer decision-making (to validate the completeness of the model's aspects), tested through quantitative surveys amongst practitioners (to validate the expected linkages of the model's aspects), and confronted with qualitative best practice SPUDP case studies (to draw lessons for effective public-private interaction in delivering such projects).

5. Conclusion

This paper introduced a conceptual model for delivering sustainable private sector-led urban development projects (SPUDPs) as first attempt to align public planning policies to market decision-making. By collecting data from literature focused on incentives and barriers experienced by real estate development actors, and taking market decisions for sustainable urban development as a departure point, this paper provided a contribution to existing body of knowledge on sustainable urban development. Furthermore, the model might assist planning policy-makers and officers to effectively design policies for and interact with market actors to achieve sustainable urban places. The findings reveal that various barriers for sustainable private decision-making need to be overcome, but that the development industry – once consciously, pro-actively and comprehensively steered by planners – might take a more active stand towards contributing to a more sustainable built environment. As the model is a result of a preliminary literature review, it remains conceptual. Findings and insights generated by envisaged future research could assist academics and practitioners to better conceive of the real estate industry's role in delivering sustainable urban places.

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Integrating Climate Responsive Principles into the Design Process: Educating the Architect of Tomorrow

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Summary

In the 20th century the world hailed a new type of construction. Following modernists' theories for minimalistic and functional buildings, a contemporary unified style based on standardization evolved into the International Style buildings.Steel, concrete, and glass-wall high rise buildings respond neither to different functional demands nor to different urban environments and climates. Such design choices influence thermal comfort and potential for natural ventilation negatively. Compensation with AC leads to higher energy cosumption.

In times of vigorous debate about rapid climate change this architectural style threatens the ecological equilibrium. Nowadays, the architect's role should be to design energy efficient buildings embedded in sustainable urban environments. Therefore, the need for corresponding principles and strategies must be included in an academic curriculum to shape conscious architects.The paper reports about experiences from a university course. It starts with an analysis comparing an International Style office room and an optimized one at 14 locations worldwide covering all main different climates. The used different tools combining energy and design aspects are presented as well as results and conclusions for the design process. Furthermore, the desire and fitting time for using climate responsive principles and the manageability of the multiple stages of design were tested through surveys distributed to students in construction-related disciplines.

Keywords: Climate responsive architecture, energy demand, architectural education, design strategies, international style buildings

3. Introduction

Buildings account almost one third of the total global energy use and contribute by one third to energy related greenhouse gas emissions [8].Currently, there is a growing demand for environmentally sustainable building solutions due to climate change and the environmental impact associated with the use of fossil fuels [9]. Additionally, the depletion of fossil fuels and the need for energy security increase the interest towards the reduction of energy consumption and the use of renewable resources.

For the years followed the first modernists' theories for minimalistic and functional buildings, same characteristic buildings regarding form, materials, type of construction appeared in many areas globally despite the differences in climate, character and geomorphology of the surroundings.The last decades the building sector is witnessing a growing trend towards adaptive and hybrid buildings [1], where the climate responsive architectural design and the application of technology for benefiting from renewable resources create a comfort, pleasant, environmental friendly and energy efficient building environment. The term adaptive presupposes a building which reaches comfort levels with only passive measures whereas a hybrid building is partly, during some months of the year, mechanically heated or cooled.

Nowadays the professional market expects from architects and planners to have theoretical and technical knowledge on how to propose creative and environmentally responsive solutions [1]. Climate Responsive Design and Planning is one of the methods for achieving sustainability in architecture [4] by adjusting the design of the building and incorporating passive strategies that benefit from the local climate and weather conditions as well as the availability of local and renewable resources. It is a necessary answer for the construction sector to climate change mitigation, depletion of finite resources (oil, gas etc.) and ecosystem agitation [1].The market demand, climate mitigation efforts and the complexity of Climate Responsive Design Principles (CRDP) themselves suggest that the departments of architecture and others related to building environment should play a decisive role in shaping the architect and planner of tomorrow.

Climate Responsive Architecture and Planning is a 5 credit points, master's level interdisciplinary course of the Resource Efficiency in Architecture and Planning (REAP) program at the HafenCity University of Hamburg [5]. It should be noted that the majority of the participants are architects, followed by a number of urban designers and planners, civil engineers and other disciplines. The course equips students with skills on how to create adaptive or hybrid buildings and renders the necessity of being aware and understand the special nature of a place and its weather conditions, principles that define a sustainable proposal.

The course is carried out through a series of lectures and assessments. It addresses the problematic nature of International Style buildings (see ch.2) regarding their energy consumption and artificial comfort they create with the help of technology. It challenges as well the students to optimize an International Style office room to the point it becomes part of a Zero Energy Building (ZEB). During the course participants realized the necessity of CRDP and the commitment it requires from the beginning of a project to its completion. Even though most of the participants were familiar with some of the principles (such as building orientation, shading, natural ventilation strategies, window placement related to openness/closeness of a place) by the end of the course many reported that the experience changed the way they create architecture.

In order to test the level of understanding, interest and perception of CRDP and whether these are currently a part of all students' academic curriculum and not only of a small percentage such as REAP students, who receive special education on matters of climate responsiveness and sustainability, a questionnaire was administered to students of all disciplines and all levels of study at the HafenCity University of Hamburg.

2. Introduction to International Style in Architecture

In the 20th century a new period begins for architecture and construction. After years of experimentation on new technologies, materials and theories, the world was mature enough to celebrate the arrival of a new epoch in architecture, in which "the palaces and houses of the future will be flooded with air and light [6]. The predominance of volume over mass, which the traditional construction techniques and forms commanded, constituted one of the main principles of the new modern movement in architecture. A branch of this new movement was the "International Style".

The principles of this style influenced many architects of the past century and played a decisive role on forming the image of many metropolitan cities around the world. The use of metal and reinforced concrete with metal bars provided the possibility of larger openings between the bearing elements of the building. This technological advanced freed walls from the main structure allowing for larger openings and a continuity in the façade creating a grill effect [6].The standardisation dictated by the construction, the economic prudency as the buildings were free from any arbitrary decoration and the theories of a mass production helped the spread of the style worldwide which is evident in many architects' decisions even nowadays.This resulted in steel, concrete, and glass-wall high rise buildings that do not respond neither to different functional demands nor to different urban environments and climates. Basic design choices frequently omitted in this type of buildings such as natural ventilation or passive solar heating can provide thermal comfort and reduction in energy consumption by benefiting from local climatic conditions.

3. Analysis of the Course “Climate Responsive Architecture and Planning”

The objective of the course was to determine similarities in architectural design solutions that responded to comparable climates and to start a dialogue on what it means to optimise an International Style room and later building, in different climates, so as to reach a desired comfort level, a zero energy demand and an acceptable human urban situation. The program succeeded to combine the theoretical background of physical laws and their practical application through a series of assessments. For the initial recommendations on passive strategies for building design in relation to climate type, the digital tool Climate Consultant [10] was used. Additionally, for assisting the learning process and testing the feasibility of the proposals we benefited from case studies, rules of thumb and the empirical knowledge of students.

The theoretical content of the course was taught in the form of a written script together with lectures that contained the following information:

- Analysis of Energy Demand
- Comfort Levels (indoor and urban spaces)
- Natural Ventilation
- Sun Protection (shading, glazing)
- Passive Solar Optimization
- Passive Cooling Methods (heat pumps, free evaporative cooling etc.)
- Photovoltaics
- Aspects of Urban Planning
- Analysis of Climate
- Compensating Measures (renewable energy)

Assessments were developed in groups of 3 to 4 students and were divided into 3 parts. Each group was assigned a city from different continents with a choice between Dar Es Salaam, Tanzania / Addis Ababa, Ethiopia / Cairo, Egypt / Chicago, USA / Mexico City, Mexico / Santo Domingo, Dominican Republic /Beijing, China / Delhi, India / Singapore, Singapore / Oslo, Norway / Hamburg, Germany / Reykjavik, Iceland /Jakarta, Indonesia / Sydney, Australia.

The subsequent steps consisted in a more in depth analysis of each city's climate provided a set of design strategies and rules to optimise at first the office room and later the building. Following this approach, each team proposed an improved building which is adapted to each climate. The optimized building was then tested for energy demand, comfort levels and energy production on-site or off-site as well as its arrangement in a real urban situation.

4. Analysis of the Assessments

As starting point a standard office room was defined with an area of use of 168 m2 (12 x 14 m) for 12 persons; with a suggested north-south orientation. The energy demand in terms of ventilation, artificial light, heating and cooling was presimulated for all locations and given to the groups.

The use of a self developed excel tool allowed the investigation of two different ways to reach a ZEB, a purist one which produces all energy on-site and an extended one where it is allowed to bring a part of the (renewable) energy from off-site (ZEB with compensating measures like wood pellets, wind turbines etc.). Thermal energy production on-site was assumed with a geothermal system (heat exchangers in the ground and heat pump), power production with PV modules on the building's roof.

The calculation of the purist ZEB ends with a maximum number of stories (limited by the capacity of PV which has to cover power demand of the whole area of use) and a minimal size of estate (limited by geothermal system which has to cover heating and cooling demand). The resulting urban situation can be discussed and compared with the real one.

The alternate scenario starts with a given (real) urban situation with more site-appropriate building height and distance. With the resulting size of geothermal system and PV modules it is possible to cover a defined part of the energy demand but maybe not all. To reach an extended ZEB the remaining part must be covered by renewable energy gained off-site. The resulting need of off-site land for such compensating measures was finally determined and discussed.

The outcome showed under which possibilities a ZEB could be reached with the chosen conditions and if the proposed urban arrangement meets the city's current situation and contributes to a sustainable and livable urban environment.

4.1 Assessment 1 – International Style building

The first task focused on a preliminary analysis of the climate on each location according to Koppen-Geiger system [7] and an investigation on local resources such as water availability and potential for energy generation and supply. The primary energy demand of the office room and the allocation of the energy required for the buildings' various needs indicated the focus point of the optimisation measures.

International Style buildings respond to a standardisation of design but are not climate responsive. Therefore, as starting point for the analysis, a standard International Style office room was selected in order to test how it behaves in diverse climates. Some typical assumptions were taken related to constructions and equipment. The room was assumed with fully glazed facades, an internal shading system, light internal construction and suspended ceilings. Air-conditioning works with 20°C for heating, 26°C for cooling, artificial light is switched on during time of use.

The investigation ends for most of the locations with unsatisfying results, Hamburg would allow for a ZEB urban arrangement of only 2.6 stories with a building distance of 34m which is out of any urban situation. During this first task students realised that in order to create a ZEB with International Style characteristics and simultaneously having an acceptable dense urban situation while diminishing the demand of the considerable amount of land necessary for the application of the compensating measures is not enough.This observation came as a result of the considerable size of land necessary for the application of PV and geothermal systems which contradicts with the density of most urban environments and an increasing request for densification. Therefore alterations and an optimal design of the room and building are required.

4.2 Assessment 2 – analysis of climate, traditional architecture, best practice examples

Designing and planning climate responsively requires knowledge and skills for analysing climate conditions and predict how these might affect the performance of buildings. For this purpose several programs are at the disposal of architects and planners. Climate Consultant [10] as one of these programs provides a detailed analysis of climatic conditions of a site and suggests passive design strategies for creating more adaptive buildings. Nevertheless, as its name suggests the tool becomes more a consultant to the user in which not all provided suggestions are adequate for all climates and locations. The right choice is defined consciously by the user. The provided by the tool design strategies, the acquired theoretical background during lecture and own research on the vernacular architecture as well as the investigation of best case studies of contemporary architecture on every location, shaped students' final design proposals.

4.3 Assessment 3 – optimized building and urban arrangement

The proposals contained the most relevant strategies which could have an impact on energy consumption and comfort levels (Adaptive Comfort Model) [2] [3]. The optimised building was examined for energy demand. A graph provided by the course, demonstrated an expected reduction in primary energy demand in an optimised climate responsive building as seen Fig. 1. Given the energy demand each month during the whole year the mode of building could be chosen to be partly or fully adaptive (natural ventilation cooling, passive heating) or partly or fully non-adaptive (air-conditioned). Effects of increased power demand for artificial light because of shadowing of opposite buildings are included as well as the possibility to use evaporative cooling or to replace partly the geothermal system by standard chiller (decreasing need of estate for geothermal system but increasing power demand). Through the excel tool, the dimensions of the standard room (width and depth) could be changed but total area of use had to be preserved.

The outcome showed under which possibilities a purist ZEB could be reached with the chosen conditions and if the proposed urban arrangement meets the city's current situation and contributes to a sustainable and livable urban environment. On the other hand, the ZEB with compensating measures is a result of own proposed building heights and distances which meets a more realistic urban scenario.

5. Results of the Course

The students were encouraged to experiment in possible design strategies that improved the thermal and visual performance and reduced the energy consumption of the office building. The final design choices for each group included proposals regarding optimal building orientation, window size and placement, need of shading systems, a natural ventilation strategy based on the on-site analysis of prevailing winds, construction type (light/heavy) and appropriate use of colors and materials. In some cases the local climate favors the implementation of exterior design strategies that affect the overall performance of the building such as vegetation and water bodies. Moreover, as mentioned in the previous chapter groups were puzzled as to how the building should be designed taking into account the site urban relationships. The results of all group assignments showed a great diversity in the design strategies and passive and technical measures as seen in Fig. 2. However, locations with similar climate indicated similar patterns. For example cities within Tropical Megathermal and Arid/Semiarid Climates tend to avoid exposure to east and west sunlight thus orienting the building north-south with some exceptions to catch prevailing winds. Constructions are lighter in tropical regions as opposed to Arid Climates. Ventilation strategies are often combined between natural ventilation and ceiling fans to improve the indoor effective temperature given the high levels of humidity but evaporative cooling functions better in dessert areas.In addition Tropical Climates allow the use of overhangs while for Arid Climates internal shading is more suitable.

On the other hand, Temperate and Continental Climates rely their orientation mainly on daylight and solar heat gains for winter while catching prevailing winds for summer cooling. Construction type is heavy for higher thermal mass and cross ventilation along with Thermo Active Building Systems (TABS) are enough to completely avoid the energy demand for AC in the summer as seen in Fig. 2. Window size is usually less than 50% of the total facade area to prevent heat losses during winter but in Tropical Climates window size tends to be larger for natural ventilation. In some areas with harsh weather conditions real ZEB with no mechanical support are not feasible, having in mind that they are embedded in a dense urban environment as seen in Fig. 2 for Tropical cities where air conditioning cannot be fully avoided.

The different design strategies and methodologies applied for creating a building with zero net energy consumption showed that there is no such “recipe” for one building in all climates and locations. Instead climate, environmental and spatial data significantly influence the design decisions and shapes the final solutions.

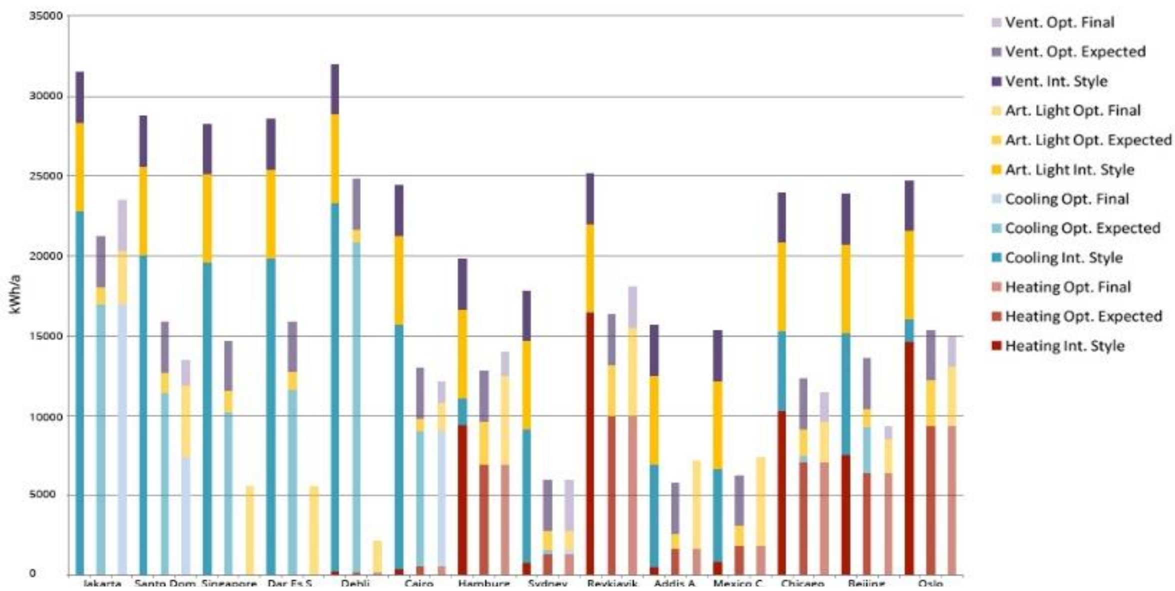

Fig. 1 Comparison of the energy demand (ventilation, artificial light, cooling and heating) expected in an International Style room, an optimised room and the students own optimised final proposal.

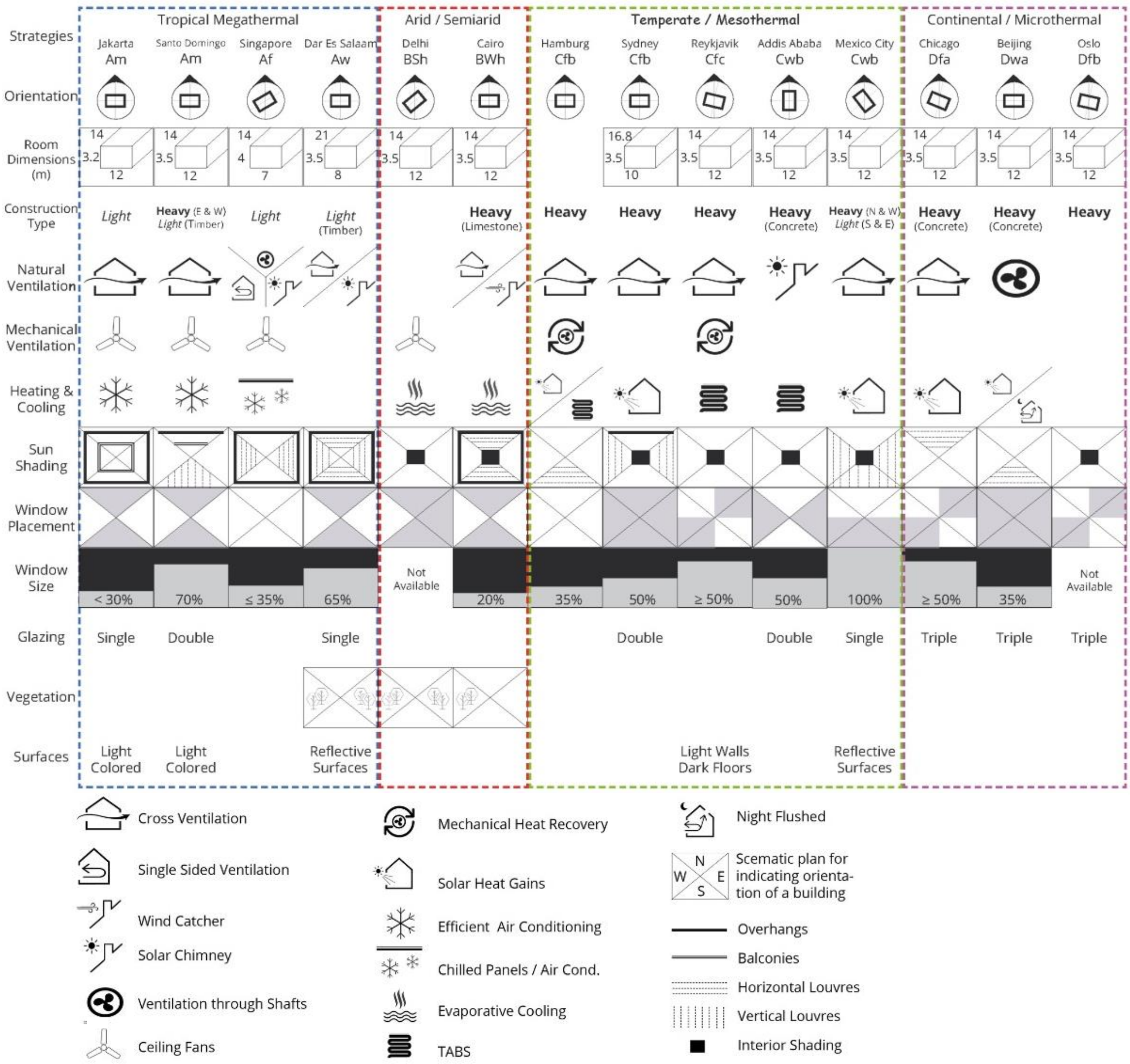

Fig. 2 Design strategies and passive and technical measures for all studied climates

The result is an adaptive and unique to each location building, with pleasant interior spaces (appropriately cooled/heated, with fresh air, well shaded) and prudent energy consumption. Particularly, in each case the reduction of energy demand between typical and optimised International Style buildings is significant. In almost all cases as shown on Fig. 1 a climate responsive design (adaptive/hybrid) and planning strategy proposed by the students (see Assessment 3) aiming to a real ZEB shows a further reduction to the energy demand of buildings from the optimised values.

The course provided a series of steps and tools on how to create more climate responsive architecture embedded into sustainable urban environments. Almost all participants' background is related to architecture and/or urban planning. Therefore, for many participants, the course made a correlation between ideas and principles already taught and followed empirically in architectural design and planning.

6. Survey and Assessment of the Course

By the end of the Climate Responsive in Architecture and Planning course participants were asked whether the information and knowledge they acquired as well as their experimentation on CRDP changed the way they understand the complex role of today's architect and urban planner and the process of conceiving a building or an urban formation. The positive response from the participants of the course was a triggering point for the last part of this research, which seeks to further investigate the level of knowledge, understanding and interest of students. The survey aimed as well to identify whether CRDP and strategies are part of the academic curriculum of all disciplines in HafenCity University and where the possible acquired knowledge stands in the conceptual design.

The research evaluates the results of 36 students, who carried out the survey. More than half of the students who took part were from the Master of Science REAP program. The students who participate to the program have a particular interest to sustainability matters and thus in the field of climate responsiveness. This possibly explains why 80% of the participants replied that they have been exposed to CRDP during their studies. This might obscure the true purpose of this research which is to investigate the thoughts of students in architecture and urban planning (bachelor and master), as typically taught, and other construction related fields regarding CRDP principles. However the results of the survey are worthy discussion and show some interesting facts.

The majority of the participants were master's students and only 28% in bachelor level. Furthermore 72% of the participants have working experience outside of the university environment which can influence their knowledge and interest towards CRDP.

The conducted survey showed that even though there is a great interest on CRDP the education on the matter is not enough. The majority reported to understand CRDP pretty well but close to 90% of participants want to be better informed and three quarters believe CRDP will have an important role in the future. Nevertheless, further improvement of the academic curriculum is required considering that more than one third of the students do not agree that their current studies include enough courses related to CRDP but fully agree that they should be included.

Additionally, to demonstrate great interest, students showed commitment to implementing CRDP into their design solutions. Opposed to what some may believe, CRDP do not hinder the creative process nor do they oppose to the traditional way of designing. Instead they are considered to be an important part in the early stages of design, have a generative (a) and corrective (b) purpose (Fig. 3), contribute to a strong design solution and are normally included in the final proposal. It should be noted that some CRDP are considered more influential for the design such as buildings orientation, day-lighting, natural ventilation and materials (Fig. 4). This probably occurs as architects use some rules of thumb and empirical knowledge taught in most universities in the first years of the architect's education.

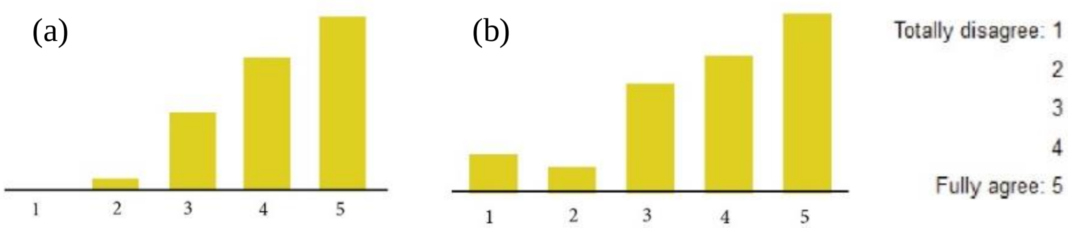

Fig. 3 CRDP have a generative (a) and corrective (b) purpose to my design

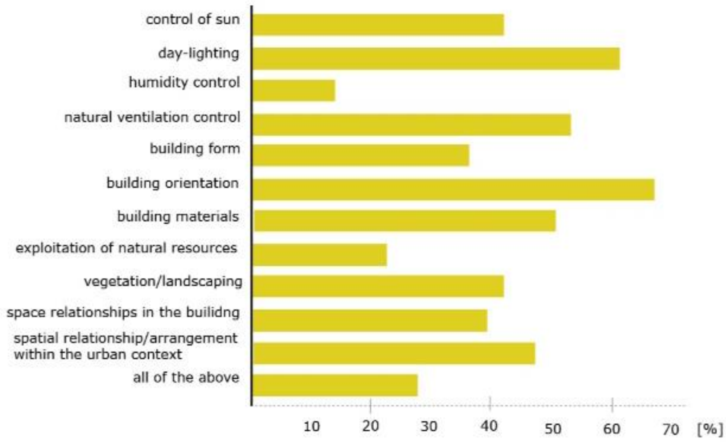

Fig. 4 Most influential CRDP factors while designing

However, there is a discrepancy on whether it is the responsibility of the architect to implement such techniques as well as a gap between the theoretical and practical knowledge. The majority of the students feel capable to apply CRDP in small scale projects but not in larger projects. For instance, larger scale projects are considered to need a team of experts and specialized consultants.

7. Conclusions

The global concerns about climate change as well as for energy security have changed the market's expectations of architects and planners and made them realize that they should take an active role on creating more energy efficient and sustainable buildings and design in harmony with the surroundings, climate and weather conditions. Many departments of architecture have realized the necessity of nurturing architects and planners with environmental related competences and are taking steps in implementing relevant courses to the curriculum, such as the Climate Responsive in Architecture and Planning course.

The different design strategies and approaches regarding building engineering that emerged during the course provide a hint of how many different and unique solutions arise from the study of climate, landscape and utilization of local resources. Participants reported that even though they had a basic knowledge of some of the CRDP the input they received during the course changed the way they might design in the future. The conducted survey highlighted the interest in CRDP from the majority of the HafenCity University students and that there should be more input on this topic. Suggestions include that the learning process of CRDP can be fostered through small scale projects and through a better integration of technical courses of the curriculum into practical and designing studios.

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Integrating Urban Ecodesign in French engineering curricula: an example at École des Ponts ParisTech

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Summary

In the era of climate change and energetic transition, industrial players are driven to adapt their activities. Eco-design has emerged as a major approach to enhance the environmental performance of products as well as services. Yet it still needs to be developed for complex issues such as neighborhood development and urban planning. This is the very objective of the academic Chair on the Eco-design of building sets and infrastructure that was established in 2008 by ParisTech and Vinci, the well-known leading group in construction and infrastructure operations. The chair involves three schools with different specializations within ParisTech: “Mines” deal with energetics, “Agro” with biodiversity and urban agriculture and “Ecole des Ponts” with transportation and urban development. The paper presents a one semester full-time specialization training for master students which was launched in 2014 at Ecole des Ponts. The curriculum, targeted to the “eco-design of sustainable cities”, is in two main parts: on the first hand, four specialist courses deal with spatial design, evaluation, urban modeling and big data, respectively; on the other hand, an intensive group project targeted to eco-design a sustainable neighborhood. The paper presents first the context of engineering education in France and its orientation towards sustainable development of cities, then the principles of the education program; next, details are provided about the specialist course in evaluation, which is based on Life Cycle Analysis, then on the intensive group project and the topics it addressed in years 2014-2015 and 2015-2016. Lastly some lessons and perspectives are drawn.

Keywords: eco-design, engineering curriculum, industry-academic partnership, built environment, transportation

1. Introduction

Ecodesign, which has developed in industrial engineering since the 1980s, is an approach to designing a product or service that focuses on greater economy of resources: parsimony, recycling and more generally a minimization of negative environmental impacts, in terms of the consumption of materials and energy, emissions of pollutants and damage to natural environments, impairment to biodiversity and human health. Ecodesign is gradually spreading into all sectors of economic activity, reflecting a general and growing awareness of sustainable development issues and an extensive commitment to energy transition and the fight against climate change [1]. Training student engineers in the concepts and methods of ecodesign, in order to prepare them for their careers serving companies and society, is an aspiration that is particularly crucial at École des Ponts ParisTech (ENPC). It even poses a major challenge to the school: training students in ecodesign in its traditional city related sphere – urban engineering, construction, transportation systems, urban services, environmental engineering – requires an understanding of the complexity of the urban environment, or at least a clear recognition of its hyper-complexity and of the need for this to be recognized in the design methods taught.

The challenge was taken up in 2014 with the creation of a specialized training, the “Ecodesign of Sustainable Cities” (ESC) specialization, in the second year of the Master program in urban (including mobility) and environmental engineering. The purpose of this article is to describe the course, in terms of its knowledge and skills objectives, as well as its pedagogical architecture. The project plays a central role, as it does in any curriculum related to urban design, combining with support courses dedicated to engineering methods, respectively for design, evaluation, modelling and simulation. The rest of this article is divided into five sections. We begin by describing the previous situation with regard to sustainable development in the ENPC curriculum (Section 2). We then go on to present the principles of the ESC specialization: aims and priorities, pedagogical objectives and methods (Section 3). Next we give a more detailed description of a dedicated support course on evaluation which tackles the Life Cycle Assessment of an urban mobility mode (Section 4), together with the intensive group project dedicated to the design of a sustainable neighborhood (Section 5). We conclude with a provisional assessment and suggestions for further avenues of development (Section 6).

2. Training in sustainable development in an engineering school

2.1 Specificities of the training of engineers in France

Every year in France, around 20,000 student engineers are awarded degrees by appropriately qualified schools, institutions that are independent of the universities (though often in partnership). Most of these schools recruit by examination following two years of preparatory classes, which succeed the scientific baccalaureate. École des Ponts ParisTech (ENPC) is well positioned amongst the twenty or so most prestigious schools, France’s elite “grandes écoles d’ingénieur”, which educate a total of some 6000 student engineers a year. These schools share the same recruitment pool and all seek a certain versatility, by each offering a fairly wide spectrum of engineering specialties. This spectrum typically includes a branch of physics, applied mathematics and computer science, as well as system management. The balance between mathematics and physics is a major feature of the earlier stages in French education, right from secondary school. Up to the scientific baccalaureate, French language and philosophy constitute a third block, and history-geography combined with foreign languages a fourth, all taught within roughly the same number of hours. In all, a French engineer is more versatile than specialized when leaving school, a semi-finished product for the professional world.

2.2 The sustainable development ministry school

Since its foundation in 1747, ENPC has trained students to become civil servants in the ministry responsible for public works and transportation infrastructures (roads and hubs such as ports, airports, etc.). Since 2007, the ministry’s remit has been expanded to include sustainable development: the technical tradition of building solid structures and operating infrastructure and service networks (water distribution, sewerage, transportation), now encompasses environmental management, i.e. the sustainable management of resources, water quality, air quality.

Former students of the School have become illustrious scientists: in the 19th century, Navier in civil engineering and fluid mechanics, Vicat in concrete, Belgrand in sanitation, Dupuit in the economic and social valuation of goods and services [2]. Closer to our time, Jean-Paul Lacaze in urbanism and housing policy, Bernard Hirsch, Jean Poulit and Pierre Veltz in spatial planning, were masterly embodiments of public action, upholding the values of technical solidity, economy of resources, the satisfaction of citizens’ needs [3]. These values are precisely the three pillars – respectively environmental, economic and social – of sustainable development.

2.3 What education in sustainable development?

The versatility of French style scientific education, delivered up to the baccalaureate, pursued through a balance between mathematics and physics-chemistry during the two years of preparatory classes (L1 and L2), is maintained in France's elite engineering schools by compulsory education in economics (micro- and macroeconomic theory, business management) and in social sciences (organizational theory, history of technology, law).
These core economic and social disciplines have recently been joined by an initiation into environmental issues: major environmental challenges, natural and technological risks.

However, even with classes relating to each of the core subjects, and a dedicated seminar on the challenges and risks, education in sustainable development remains superficial and somewhat passive. In order to inculcate an in-depth understanding of the issues and principles, specific methods need to be taught and practiced by the students in an active role, from the designer's perspective. This is now well recognized in engineering programs for particular technical specializations, notably taught through project-based courses. It still needs to be applied for a specialization in "sustainable development".

2.4 The VET department: seeking to integrate the three core elements

What still needs to be taught is a hard core of concepts and methods relating to the economy, society and the environment, including analytical methods that can be used in design offices, together with operational methods that are applicable in the field. That has been the aspiration of the Ville-Environnement-Transport (VET – City-Environment-Transportation) faculty department in the Masters program, since its formation in 2002 at ENPC to deliver an in-depth curriculum focusing on sustainable development. The City component relates to social issues and spatial planning principles: design, coordinated decision-making, public action, urban services. The Environment component is divided into the hydrological and the atmospheric environment, each with its physics, its chemistry or its biochemistry. Environmental engineering also includes system evaluation and management methods. In Transportation, the basic courses deal respectively with systemics and modelling, traffic engineering, transportation economics. In the VET Department's first five years since its formation, the student program included a compulsory hard core in each of the three components, in addition to the seminar dedicated to interactions between them. This very tough combination was based on a set of more easily combinable short courses (18 hour modules), put together through a breakdown of pre-existing courses [4].

In parallel, integrative courses were established:

- The basic environment program deals with the big themes (water, energy, life, weather and climate), each with its own course program. It takes place in the first year (Year L3).
- In the first semester of the first year of the Masters degree (M1), the MASYT course (Analysis Methods for Territorial Systems – 40 hours, 5 credits) teaches systemic analysis of an urban area successively through geography, demography, sociology, economics, the real estate system, the mobility system, environmental impacts. The theoretical courses are applied in supervised practical work based on a Geographical Information System (GIS) supplied with a full set of thematic databases, and in a mini-project undertaken in pair-work on a case of territorial assessment and planning design [5].

In the second semester of the M1, the TAMUR course (Transportation and planning in an urban and regional environment – 80 hours, 8 credits) deals with methods of socio-economic evaluation and spatial planning in a deeper way. Half the course consisted of a team design project (e.g. eco-neighborhood design, company travel plan, territorial energy forecasting). [6]
Since 2010, the VET program has been reorganized with a stronger emphasis on the integrative courses, and the compulsory grounding in a hard core in each specialty has been replaced by registration in a singlwe specialization in order to achieve a more in-depth understanding. Thus, for a student engineer in the VET Department, the first year of the Masters program (M1) is a combination of integrative courses and a particular specialization.

3. The specialization in Ecodesign of the Sustainable City (ESC)

At the beginning of academic year 2014-2015, ENPC created a dedicated specialization in the Ecodesign of Sustainable Cities (ESC). It is administratively and pedagogically attached to the VET Department, but also open to other departments in the Masters program: Civil and Structural Engineering, Mechanical and Materials Engineering, Mathematical Engineering and Computer Science, Industrial Engineering, Economics-Management-Finance. The aim is to draw on a sectoral specialization acquired in M1 and then to broaden it to the three areas of City-Environment-Transportation and thereby to the three core dimensions of sustainable development.

3.1 Thematic positioning

The title of the specialization states its purpose [7]:

- The City as a complex ensemble, extended in space, containing a population in buildings and open spaces for a diversity of activities: housing, production and consumption of goods and services, movement and social life in general. This space has been gradually developed through shaping and artificialization, with a variety of amenities, in particular the real estate stock and technical infrastructures.
- Sustainability in its three pillars – society, economics and the environment.
- Ecodesign in order to emphasize the environment and adopt the position of the designer, capable of identifying and exploiting synergies between the different pillars, and to convert constraints into opportunities.

Urban transportation reveals the synergies between the three pillars and the advantage of acting on systemic effects: there are both financial and environmental economies to be made by concentrating mobility in mass transit vehicles. High urban densities, which determine the scale of trip flows, reinforce the environmental stakes at local level and bring individual interests in line with collective interests, by making mass transit services efficient for individual passengers.

3.2 Knowledge and skills objective

The knowledge objective is to reach an advanced understanding of the issues, with their challenges, their respective whys and wherefores, and in particular their interactions and functional links. This advanced understanding is manifested in a capacity to express the phenomena and impacts qualitatively and to connect them together. A student engineer also needs to be able to translate a particular aspect into one or more indicator(s) that depict it with relevance and measure its state along significant dimensions. The skills objective first concerns the ability to quantify the physical, economic, social and environmental aspects: modelling by variables and causes, simulation models applied not only as black boxes but also understood in their operational mechanisms. Alongside evaluation and modelling, the skills objective also includes conception: the ability to propose configurations, scenarios, management processes for a particular case, in operational regimes both regular and transitional (e.g. construction site) – which reinforces the importance of involving the system's different stakeholders in the conceptual process.

3.3 Course structure

The specialization consists on the one hand of specialist modules called “support courses” and on the other hand of an intensive group project, accounting for more or less equal parts of the student timetable in the first semester of the second-year Masters program (M2).

There are four support courses, each of which cultivates a particular competence:

- The ACVMU course covers the Life Cycle Assessment of an Urban Transit Mode, combining methodological inputs and team-based practical application to a study case. The case concerns an urban travel mode, so that both infrastructures and vehicles are involved [8]. Details of this course are set out in Section 4 below.
- The MMAUR course deals with Modeling Methods and Urban Applications. It develops around two complementary axes: the first direction delivers a range of modeling approaches, the second direction spans different urban subsystems. Each axis encourages comparative analysis, critical examination and critical distanciation [9].
- The CSIUR course, Spatial Design and Urban Integration, focuses on design. Space is treated both as a resource and as a node at which different constraints connect together.

Technical intervention on space, the use of space, its arrangement and artificialization through infrastructures and superstructures, is taught by a consultant engineer. However, the teaching team is primarily made up of architects who talk about their professional practice and present theoretical strategies for acting in and upon space. In particular, in the urban environment the negotiating power of citizens governs the notion of compensation: this forces an expansion in the development project, so that it becomes a genuine urban project and therefore provides greater value, even if at higher cost [10].

- The GRAVED course on Data Management, Collection, Analysis, Visualization and Enrichment, teaches the representation and handling of large datasets, with applications to transportation and real estate [11].

As for the intensive group project, it is conducted in teams ideally comprising 4 to 6 members. The objective is to pool sectoral skills around a joint application. Collectively, the primary aim is to manage intersectoral complexity and to conceive a development operation that is satisfactory in all aspects of sustainable development. Further benefits come from the learning of teamwork methods and external communication in interaction with outside actors, some of whom are potential clients. In addition, there are individual learning objectives: (1) for effective sectoral design, (2) for working successfully in close cooperation. Details on the process of the intensive group project and its results are set out in Section 5.

4. Course on “Life Cycle Analysis of Urban Transportation Modes”

4.1 Knowledge and skills objectives

This module teaches Life Cycle Assessment (LCA) methodology, particularly for transportation systems. It seeks to equip student engineers with the skills to handle evaluation studies and research on the environmental performance of urban transit modes. LCA is an ISO 14040 and 14044 classified assessment methodology that is used to quantify the environmental impacts of a given system over its whole life cycle, from the extraction of the raw materials needed for its development through its use right up to end-of-life. Currently, optimizations relating to transportation systems are highly sectoral, divided between vehicles on the one hand, infrastructures on the other and, between them, traffic optimization. However, an urban transit mode is a complex system in which numerous interactions can take place: “optimal optimization” necessarily requires the mode to be assessed as an integrated system, over a larger than usual physical perimeter. The complexity of transit systems reaches its apogee in urban environments, where the density of demand – which supply seeks to fulfil – entails a diversity of modes and therefore a multiplicity of possible combinations within an itinerary, generating substitutions and/or intermodality on the part of travelers, and lane juxtapositions and traffic mixes within the system, which themselves generate conflicts between mobile units. The objective of this module is both to pass on the theoretical and practical elements of LCA, and to teach students how to apply them in a close-grained way to transportation systems. This second aspect constitutes the state-of-the-art in the environmental assessment of transportation systems, since LCA methodology was initially developed for the ecodesign of simple manufactured products. As regards the pedagogical structure, the module is built around 13 sessions of 3 hours, comprising an initial series of lectures followed by a project-based case study.

4.2 Lectures

The first four sessions provide the essential theoretical grounding, in a very restricted timeframe: first the environmental issues associated with the transportation sector, LCA methodology, and its sectoral use in application on the vehicle side and on the infrastructure side in France, continually punctuated with exercises in application to promote the practical assimilation of the concepts. Conducting a LCA requires a certain technical knowledge of the system studied, without which there is a risk that the model will contain omissions, replications and errors and inaccuracies. For this reason, the two lecturers sought to put across the rudiments of the construction of the systems constituting a transportation mode. The lectures were combined with two sessions of bibliographical reading (individual work) followed by class feedback.

4.3 Case study: eco-assessment of a BRT system

The project group is structured rationally to handle the case study. It followed the stages of a LCA: (i) Consideration of the study framework, selection of study objectives and the perimeter of the system studied; (ii) Establishment of inventories based on documents supplied by our industrial partners (designers, constructors, suppliers and operators of the transportation system); (iii) Implementation using the OpenLCA software, reflection on the environmental indicators chosen and acquisition of the potential impacts; (iv) Study of the results and correction of modelling errors through close analysis. From phase (ii) onwards, the students organized into pairs or individually for each system element in order to model the infrastructure. This organization arose quite naturally from the source documents conveying the basic information used in establishing the inventories: this document was the Indicative Bill of Quantities of the infrastructure constructor Eurovia, which was also organized into system elements. This was a very large document: 600 Excel spreadsheet rows in the basic document, with a further 7 detailed files containing up to 75 tabs, each with a few Excel rows. The process of establishing an inventory consisted in dividing up the so-called operations (i.e. lifecycle stages of construction, operation, end-of-life) for the whole system, conducting a materials assessment (materials, energy consumed in different forms), and then identifying the most appropriate modelling processes in the EcoInvent database. This required a very close analysis of EcoInvent. The eight workshop sessions were headed by the module's two tutors: their role was both to verify accomplishments as they occurred and to support the students, usually on request, in establishing working hypotheses and in progressively verifying the magnitudes. The small number of students – just eight – meant that they could be closely monitored in classes and then in the project workshops. Their work was assessed on the basis of the quality of the bibliographic study and their communication in class, the relevance of their modelling, and the accuracy of the results obtained. Not all the results could be exploited, even when the most significant mistakes were corrected by the tutors. For example, the "wastewater management" subsystem had to be excluded from the perimeter, pending revision. Out of a set of 13 indicators selected to cover the main categories of environmental issues quantifiable by LCA, the study gives the contribution of each subsystem to every indicator describing their types of impact. The subsystems can be more or less finely divided, depending on the information sought: infrastructure/vehicle or a more detailed level, focus on green spaces (per life-cycle phase), on street furniture, etc.

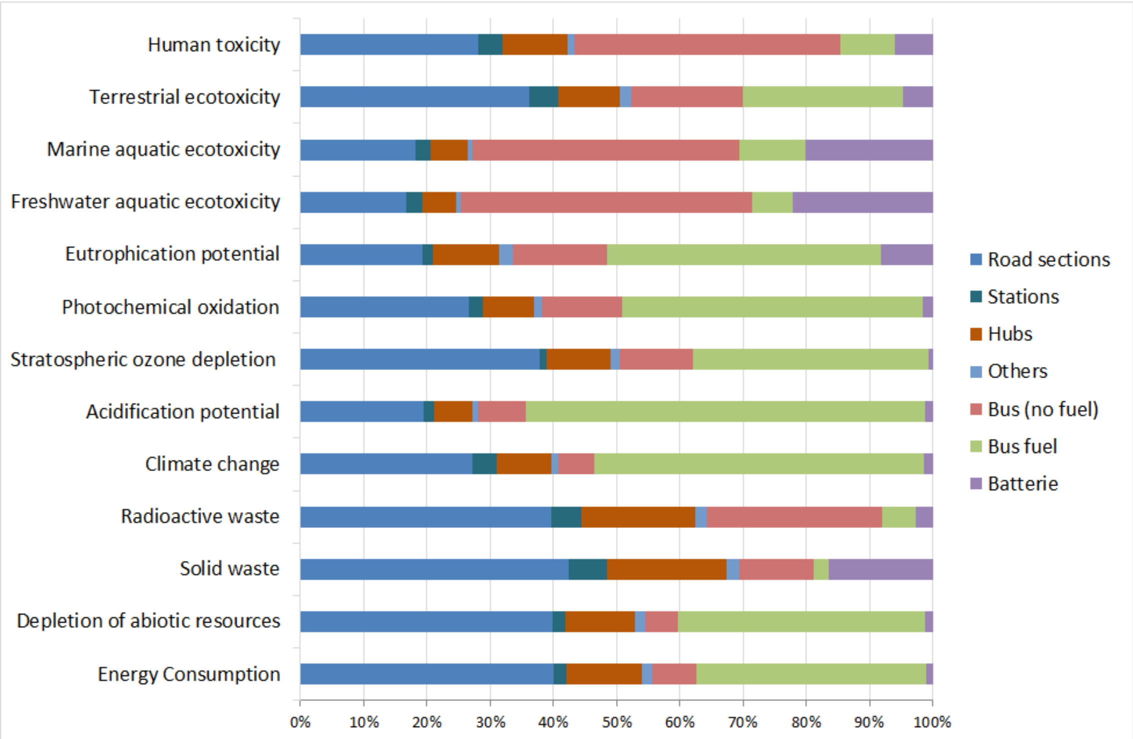

Figure 1 Example of results

4.4 Critical assessment

Although the LCA methodology claims to be global, it in fact provides neither the local environmental impacts that directly affect populations adjoining the transport infrastructure – air quality and urban ambience (noise, odors, landscape…) – nor the quality of the transportation system for users, which could be measured, amongst other things, by accessibility indicators.

In pedagogical terms, the module offers two advantages. First, it places the students in a complex professional situation – teamwork, data that are highly complex to handle and at first sight not very comprehensible/familiar, use of previously unknown software and database. Second, it places them at the heart an advanced subject with so far very little spread at national level, the development of an assessment methodology for an integrated transportation system, on a larger perimeter ([12], [13], [14]) or with more indicators ([15] than usually.

Since a detailed LCA (i.e. an ex-post assessment) is highly time-intensive and less useful for developing recommendations that are actually usable, it was decided to develop an ex-ante LCA and to conduct sensitivity analyses in order to place the students in a real-world situation of providing client advice.

Finally, the study was extensively publicized with industrial partners in the project and at a worldwide professional conference (25th World Road Congress), which gave half the year group – i.e. those who had delivered usable work – the opportunity to co-author a first article. Nonetheless, the tutors had to intervene extensively in order to verify and revise the models and obtain valid results.

5. The intensive group project on “ecodesign and planning”

5.1 Knowledge and skills objective

Let us recall here what was specified in paragraph 3.3: the body of knowledge to be acquired relates to subjects that are components of the sustainable city: (1) the built environment and urban morphology, (2) mobility and transportation, (3) energy and materials, (4) water and the blue infrastructure, (5) biodiversity and the green infrastructure, (6) stakeholders. The skills for development are modeling and simulation through acquisition of the principles and implementation of simulation software tools, as well as evaluation and the design process [16].

5.2 Project structure and process

Here, the project aim is to design a sustainable neighborhood. This entails designing a layout plan (land-use and spatial arrangement in 3-D, at each of the locations within a demarcated perimeter), in terms of urban functions (housing, amenities, economic activities of several types), each of them in certain places and with certain intensities, with material amenities (buildings, networks) requiring proposals for form and scale, as well as fine-grained arrangement for elementary functions (e.g. layout of external access points and parking spaces for a given building). This plan must fulfil a set of functional specifications imposed by a commissioning client: typically, for the number of inhabitants and jobs to be contained, the areas of floor space to be built, land occupancy ratios; and, at the same time, it must offer good performances against multiple sustainable development assessment criteria [17].

This standard project was implemented in 2015-2016, by a group of 8 students, for a district in Cité Descartes in the eastern suburbs of Greater Paris. This district will be served by the Grand Paris Express automatic subway system in 2025, and urbanization will be intensified. Figure 2 shows (a) a satellite photo of the site and (b) a site plan. Four topics will be studied in depth: the buildings, mobility, energy and hydrology. Air quality will only be considered in terms of road traffic emissions.

The semester allocated to the project (in fact less than 5 months) is structured into four phases: First, revising and obtaining knowledge, together with the learning of simulation tools; Next, application to design, by modelling the study case and devising a planning choice (a “variant” of the project); Then the multi-criteria assessment; Finally, following an intermediate presentation to the stakeholders, a project redesign and the assessment of the new variant, for final presentation.

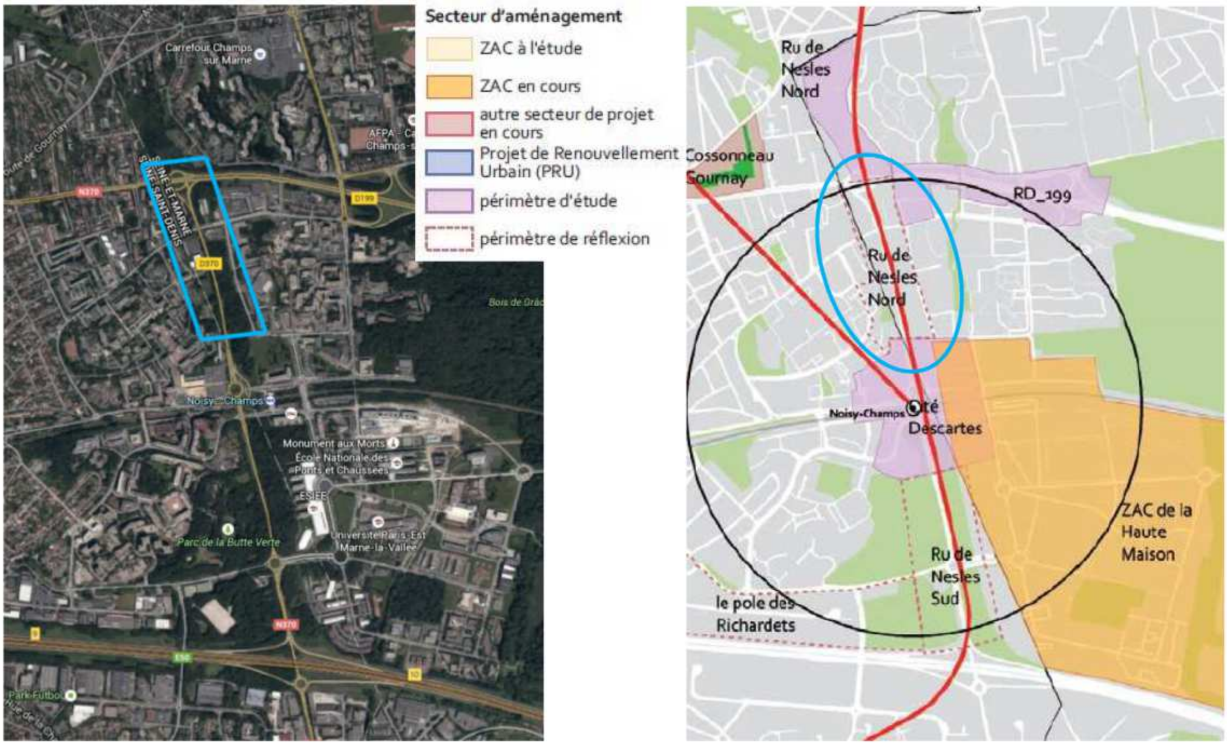

Figure 2 Neighborhood under study (a) Satellite view, (ii) Situation map

5.3 The Descartes showroom project

In 2014-2015, the first year of the new program, the first project was deliberately simplified in order to test the students’ ability to handle an extended range of knowledge input. The task was to design an overall assessment for the concepts, products and services focused on the theme of the Sustainable City by organizations and companies located at Cité Descartes, a scientific campus in the eastern part of Greater Paris. This group includes public education and/or research bodies (ENPC, IFSTTAR, CSTB, CEREMA, Université Paris-Est Marne la Vallée) as well as large companies associated with these public institutions and others within the Efficacity Institute for Energetic Transition (IET): EDF, Engie, IBM, Véolia, Vinci and an engineering consortium. The category also includes innovation companies, in particular MopEasy (different forms of car rental) and Moviken (mapping). The assessment goal was gradually restricted to a fraction more easily accessible to the students: the work of the Chair in the Ecodesign of Buildings and Infrastructures (an association between ENPC and the schools of Mines and Agro ParisTech) [18], the EIT Efficacity projects, the Université Paris-Est Great Hall project, and a few private sector services. This pedagogical framework enabled the students to grasp the major stakes and also the main engineering components of the Sustainable City. The students divided up the work to concentrate more specifically on each of the following six major components: (1) Urban morphology, (2) Transportation and mobility, (3) Energy, (4) Environmental assessment, (5) Biodiversity, (6) Stakeholders, and then brought the components back into interaction. During the project, they produced: A report with their own presentation of the components together with their design approach [19] ; Posters explaining each component from a four-fold perspective: from Priorities to Prospects via Projects and Productions; A “7 Families Set” of the sustainable city, a discovery card game; each family contains six members, representing each of the six components. The families are “Functional and Socially Interactive City”, “Circular Economy”, “Smart and Connected City”, “Resilient City”, “Green City”, “Renovated City”, “Today’s City” ; A “Board Game” for assessing the life cycle of a concrete wall ; Plans for the layout of a demonstration space: a layout map divided into circuits covering the major components. The exhibition material was displayed for a week, from February 9-14, 2015, at the Bienvenue Building in Cité Descartes, in the central hall's so-called "green bean" room. In the event, it also included several loaned objects, notably provided by IFSTTAR to demonstrate the concept of 5th Generation Road, while ESIEE loaned several Sense-City equipment sensors.

5.4 Observations

The first year group and the beginning of the second have shown that the students are strongly committed to the project. The linkage between the support classes and the intensive group project facilitates and stimulates the team dynamic. The students work hard to understand the topics pursued by their colleagues and erstwhile classmates, as well as the themes they model and simulate themselves. Contacts with the stakeholders are an opportunity to discover the need to communicate in a clear and targeted fashion, and conversely to deal with vagueness or even contradictions in the expectations and needs of the different stakeholders.

6. Conclusion

6.1 Assessments

On the basis of just the first year of implementation, the assessment of the ESC specialization is very largely positive.

The researchers who taught the course and the intensive group project are very satisfied with the high level of student commitment and the quality of the results. In several courses, the processes carried out and the results obtained formed the basis for a scientific paper presented at an international conference. The small numbers allow rich and fluid interaction between tutors and students.

The students commented on the very heavy workload, while stating that they would still choose to take the course if they had to start over. The group dynamic, driven by the strongest students, enabled the less advanced to gain confidence in their own technical capacities, and therefore to gain personal poise and self-assurance in their working relations.

Following the semester of learning, each student produced their Masters assignment on a subject very well aligned with the specialization. Their understanding and technical competence were very quickly recognized by their employers. As a result, the content of their employment roles has been enriched, to the benefit of both employer and student.

In all, the new training system opens up the students to a wider technical spectrum, and makes their learning more productive. In other words, the program itself is much more effective than the previous system.

6.2 Future developments

We infer that the young engineers who have experienced the new training can more quickly or deliberately access responsibility as heads of development projects, and therefore as operation coordinators. Indeed, it would seem that the education process has helped them discover the diversity of possibilities in a cooperative perspective, by overcoming mutually imposed constraints and showing ways of reconciling them harmoniously.

According to the design offices which recruit engineers trained by ENPC, this coordinating engineer profile is nowadays only too rare, and therefore much in demand. By adopting it, our young engineers will make themselves useful not only to their employers, but also of course to society, by reinforcing the effectiveness of public action.

7. Acknowledgements

The new course program was created with the support of a number of people and organizations. First, we would mention the tutors, who played a very committed and dynamic role in establishing the new programs, both support courses and projects, as well as the VET Department's managing team, in particular Joachim Broomberg. We will also mention Professors Bruno Peuportier and Jean Roger-Estrade, of the Chair in the Ecodesign of Buildings and Infrastructures, jointly supported by the Écoles des Mines, d'Agro and Ponts ParisTech: the Chair inspired the program and actively supports it. We also thank the Vinci group which sponsors the Chair, in particular our copilots Maxime Trocmé, Christian Caye and Christophe Gobin. Finally, the Efficacity Institute, and in particular its chief executive Michel Salem-Sermanet, hosted the group project workshop and stimulated it on numerous occasions. Our warmest thanks go to all of them

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Integration of building performance simulation tools in an interdisciplinary architectural practice

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Summary

With ever-expanding demands regarding both the energy performance and the occupant comfort being placed on modern building design, architects are increasingly using a rapidly growing range of building performance simulation (BPS) tools in order to optimize their designs, give a quantitative measure for design ideas, or to ensure compliance with a range of legal requirements and optional environmental certification schemes such as LEED and Breeam. Increasing focus on near-zero-energy and positive energy buildings has, for instance, led to facades and roof areas being considered not only as structures providing shelter but also as possible sources of energy, due to solar irradiance.

The aim of this paper is to explore how a large architectural practice categorises, evaluates and embeds building performance simulation tools, into its work practices. The paper outlines the process of identifying tools in an interdisciplinary project environment, evaluating their potential use in different types and stages of a project and how their use is integrated into workflows.

Results of the paper show that the selection and application of BPS tools in practice corresponds to a significant degree with previous research. It also demonstrates that the lack of independent comparison of BPS tools leds to significant costs for practices with regarding to selection of which tools they should use. A key recommendation would be a creation of third party comparison of tools, with results open to all and continuously updated, in order to reduce this cost.

Keywords: Practice, building performance simulation tools, daylight, energy, organisation

1. Introduction

The aim of this paper is to describe the process by which a large architectural practice identifies and selects appropriate Building Performace Simulation (BPS) tools in an interdisciplinary project environment, evaluates their potential use in different types and stages of a project and how their use is then integrated into workflows. The paper explores the practical application of BPS tools and compares it against existing academic research. The paper is aimed towards a broad audience, to serve as a reflection of praxis within architecture practices, to expand on, and contribute to the debate regarding how BPS tools are selected, evaluated and used, as well as to cast a critical eye over the administrative task of integrating their use into the architectural projects' workflow.

An ever increasing demand exists for architectural practices to adopt digital design tools to inform design. Among them, Building Performance Simulation (BPS) tools allow simulation of a building's performance with regard to several metrics, mainly energy, daylight, thermal comfort and solar irradiance. Increasingly buildings are also subjected to various third party building certification schemes, such as LEED and BREEAM and the Swedish system Miljöbyggnad, which require quantifiable energy and daylight calculations in order to show compliance.

The architectural practice studied is White Arkitekter, a Swedish based practice which is one of Scandinavia's largest practices. The practice traditionally has had a focus on sustainability and has specialists in different areas of sustainability such as social sustainability, ecosystem services, materials, energy, daylight, etc. In this group, around 12 people are specialised in daylight and energy modelling, although an increasing number of non-specialised architects are using daylight simulation tools on a more sporadic basis.

2. Methodology

2.1 Case Study

This paper focuses on describing the process as is, i.e. how White currently uses processes and frameworks to select and incorporate BPS tools into their internal process. As the company has several offices, in different countries, and works on projects of vastly differing complexities and demands, the case in this paper is White itself, as a central company, as it is at the central level that decisions about which tools are used and how they are incorporated into projects are taken.

A case study has been described aptly as "the vehicle by which a chunk of reality is brought into the classroom to be worked over by the class and the instructor. A good case keeps the class discussion grounded upon some of the stubborn facts that must be faced in real life situation"[1]. In the increasingly congested field of academic articles regarding building performace simulation, a case study dealing with one company is a welcome addition, as, as a quick glance shows, the majority of papers published are with regard to comparing different BPS tools or looking at the use of BPS tools on a project level. Here, the focus of interest is lifted a level higher, to the organisational company level.

The authors of the paper have been employed by White Arkitekter for the past 3 years. This paper builds on their experiences in driving and forming a consistent approach to the use of energy and daylight modelling as White expanded these competencies from being based only at its largest office to be more spread out over different offices. In order to facilitate this increase, the authors were tasked with gathering a team of specialists in Building Performance Simulations. The main function of this working group, which is still active, is to define processes, build methods, assess BPS tools, and ensure knowledge transfer to architects, as well as the continuous development of new skills within the team of specialists.

2.2 Literature Review

Literature regarding building simulation has two dominating categories; those that deal with the modelling capabilities of BPS tools, and those that deal with the application of such tools. The first category focuses on how diffierent BPS tools model accurately various technical solutions, whilst the latter focuses more of the user experience of the tools, often contrasting the preferences of architects and engineers for different features. In selecting and using a BPS tool across an organisation it is necessary to interweave these two categories, tools selected must be robust and accurate, but they should also fit the purpose, stage and user for which they are selected.

Difficulties in comparing BPS tools against each other is not a phenomenon that has gone unnoticed by researchers. The simulation community does not yet have clear criteria to classify and evaluate the facilities offered by different tools [2], because the tool developers rarely state the tool's capabilities and limitations [3] and because there is no common language to describe tools' capabilities [2]. Similarly, other academics bemoan the lack of uniform definitions of tool requirements and specifications [4]. In 2002, although Augenbroe did not address tool evaluation criteria in particular, the paper presented trends in building simulation, regarding interoperability, knowledge base integration, and adaptability [5].

According to Attia [4] the two most significant studies are the ones of Lam et al. in 2004 and Crawley et al. in 2005. In the first one, a classification scheme was developed based on four major comparison criteria: usability, functionality, reliability and prevalence and in the second one, the capabilities of 20 major digital design tools were compared. The comparison criteria were based on vendor-supplied information with 18 categories including: results-reporting, validation, user-interface and links to other programmes [2]. In 2012, an attempt to organise criteria into 5 categories was made [4], as described in the figure below:

Abbreviation	Selection criteria and keywords
	Usability and information management (UIM) of interface
UIM	The 'usability' incorporates the functional operation of a tool. **Keywords: output and input representation, navigation, control, learnability, documentation, online help, error diagnostics**.
	The 'information management' is responsible for allowing assumptions, facilitate data entry and control the input quality. **Keywords: input quality control, comparative reports creation, performance benchmarking, data storage, user customization, input review & modification**
	Integration of intelligent design knowledge-base (IIKB)
IIKB	The knowledge-base supports decision making and provides quantitative and qualitative advice regarding the influence of design decisions. **Keywords: pre set building templates & building components, heuristic/ prescriptive rules, procedural methods, building codes compliance, design guidelines, case studies, design strategies**
	The intelligence entails finding quantifiable answers to design questions in order to optimise the design. **Keywords: context analysis, design solutions & strategies optimisation, parametric & sensitivity analysis, 'what if' scenarios, compliance verification, life cycle and economical analysis**
	Accuracy of tools and ability to simulate detailed and complex building components (AADCC)
AADCC	The accuracy of tools includes analytical verification, empirical validation and comparative testing of simulation. **Keywords: BESTEST procedure, quality assurance, calibration, post-construction monitoring, error range**
	The other part of this criterion deals with the ability to simulate complex building components with high model resolutions. **Keywords: passive technologies, renewable energy systems, HVAC systems, energy associated emissions, green roofs, double skin facades, chilled beams, atria, concrete core conditioning, etc.**
	Interoperability of building modelling (IBM)
IBM	Interoperability corresponds to the ability multidisciplinary storing and sharing of information with one virtual representation. **Keywords: gbXML, CAD, IFC, BIM, design phases, design team, model representation**
	Integration with building design process (IBDP)
IBDP	IBDP corresponds to the integrating of BPS tools during the whole building design delivery process. **Keywords: multidisciplinary interfaces, design process centric, early & late design stages**

Fig. 1 Building performance simulation tool selection criteria [4]

Attia [6] has described the germination of the modern BPS tools into three specific periods. The first is the creation of the earliest tools in the 1960's and 1970's which were concerned with calculation of a building's thermal performance. The next period, from the late 1970's into the 1980's, dealt mainly with developing codes and methods for validating these tools. In the 1990's a gradual widening of the scope of BPS tools from a focus on energy consumption, towards other parameters such as lighting etc. occurred. This final period led to greater utilisation of the tools by the building design profession. Accordingly Attia sees four major changes associated with the final stage of development, namely:

- A diversification of tool users and a broadening of scope with the entire design team
- The modification of tools towards early or late stage designs
- A rapid increase in the number of tools available
- The 'localisation' of tools, i.e. the ability to include local weather files, local building regulations and materials [6]

This final stage is a description of the situation which is prevalent today. The rapid increase in tools has not always translated into a greater choice of tools for use by professional organisations. Among the 456 tools listed on the US Department of Energy (DOE) Building Energy Software Tools Directory website, only 75 of have been updated since 2014, and thus can be considered seriously as potential tools for use by architectural practices [7]. As the choice of BPS tools increases, along with their cross discipline functionality, increasing focus is laid on the interaction between different parties in a project. Negendahl [8] demonstrates this by discussing the increasingly weak barrier between the geometrical model and the calculation model. The ability to use plug-ins from the calculation model to the geometrical model, allow increased overlap between the models, leading to increasing friction over ownership of the procedure. Whereas previously the focus has been on the engineering aspects of building simulation, which by its nature requires many of the design parameters to be 'locked' or decided upon already, the new focus on optimising the passive features requires that BPS tools are used earlier in the process and that the onus for using them shifts more from the mechanical services engineers to the architect. This has led to increased use of these tools within architectural practices.

How practices organise themselves differs greatly depending on a range of factors, such as size, number of locations, profile etc. An article in the industry journal Detail, by Emanuele Naboni explored this development within the industry. Of the ten practices interviewed, nine had created separate sustainability teams whilst one practice had integrated building simulation into their entire workforce. The typical framework has been dedicated sustainability teams that then plug into the different project teams. Naboni describes this role of the sustainability specialist as "an active interpreter of results, and an active agent in the transfer of data for an informed design process"[9]. Furthermore the author describes the different way in which the practices predominantly organise the interaction between the design team and the building simulation expert. These can be characterised in three different ways:

- **Definition of criteria**. This is where the building simulation expert at an early stage helps to define the criteria and associated rules of thumbs to be applied to the project, with simulation at a later stage to evaluate the design. In this case, one could describe the simulation expert as an advisor in the early stages.
- **Scenario by scenario**. An iterative process involving close cooperation between the architect and the simulation specialist. Here a series of different scenarios are simulated in order to continuously move the design towards the optimum solution.

- **Form finding**. An approach based on the power of parametric tools. This algorithm-based method involves defining the performance criteria for a range of targets and using parametric performance software to find the best fit form for the range of criteria.

Naboni's work further moves forward the debate from the basis of tools to their integration into the workflow. It raises the subject of organisation within the practice and between simulation specialist and project. By describing the three different approaches that are used by the practices interviewed, the article touches on the realisation that these approaches have a large impact on how workflow within the practices must be organised in order to achieve the wished results.

3. Results

3.1 Assessment and selection of BPS tools: Case of the evaluation of an energy and daylight tool conducted at White in 2014

The following example describes the process used by White during a recent evaluation BPS tool. The evaluation was conducted in the fall 2014. Initially, the tool had been identified as of interest due to its potential to be used as an early design tool, its ability to deliver 'real-time' results and that it operates via a 'plug-in' to Revit, the predominant geometry tool used by White. By identifying the aims of the evaluation (cf. Table 1), it was possible to build a framework and allocate resources. Crucially this first stage identified that a group larger than just specialists was required, and that architects needed to be involved in the process. Eight people were involved, 4 specialists and 4 architects. Each was allowed to propose different tests representing issues that were pertinent to how they use, or wish to use the tool.

Table1: Assessment goals and distribution among evaluation team

Person	Evaluation goals
1	Robustness of results when performing an energy calculation / Comparison to results obtained for the same case with another program
2	Robustness of results when performing a daylight calculation / Comparison to results obtained for the same case with another program
3	Compliance to the the iterative, integrative, collaborative and real-time process. Possibilities for comparison of geometries / alternatives for optimal im early design stage / decision making
4	Usability for verification for certification schemes (Miljöbyggnad, LEED and BREEAM) for energy, thermal comfort and daylight
5	Developers vision, accordance to White's vision / policy, licenses, maintenance, training, etc.
6	Ability to handle complex geometries, specific design objects (curtain walls, links, design options in Revit for instance) Import of geometries coming from different file formats
7	Continuity between the Plug-in and the Application Storage and extraction of results and data Possibilty of visualisation of the results
8	User friendliness and learnability by architects / by simulation specialists

Over the following week these different tests were conducted by the group and the issues discovered were collected and communicated with the tool vendor (cf. Table 2).

Table 2: Initial classification of the assessment criteria given the results of the team's evaluation

General considerations	Interoperability considerations	Specific considerations
User friendliness	Availability of guidelines for modelling the geometry	Customisation possibility of inputs
Adapted simulation time by stage and use	Limitations regarding model geometry	Availability of default input values and calculation parameters
Instant visualisation of the results and automatic update of the results (Real-time)	Amount of work necessary on the geometric model before being able to run the simulation	Control over the calculation parameters / analysis settings (level of the analysis plan for instance)
Learnability	Ability to handle models from different formats	Customisation possibility of outputs (metrics, formats, visualisation, etc.)
Suitability for early design stage	Export possibilities of the results and data	Availability of calculation guidelines
Quality, reliability and responsiveness of the support		Possibility to compare scenarii
Effective detection of errors and fixing directions		Possibility to simulate complex geometries and systems
Adapted use and complexity by user profile, competence level and stage		Capacity to verify and justify the compliance to Standards, Certifications and Labels
Adapted use for multidisciplinary project teams (sharing, rights, synchronisation, etc)		Quality assurance / Conformity to the standards for Energy and daylighting programs (such as ASHRAE in the US, BBR in Sweden, etc)
Possibility to conduct sensitivity analyses		Accuracy (Reliability and Validity) of the results
Continuity between project stages		Transparency of the method and results
Cost, maintenance and training		Capacity to make optimisation recommendations

Below, an attempt was made to group these criteria according to Attia's 5 categories (cf. Figure 1).

Table 3: Classification of the assessment criteria according to the five categories identified by Attia

UIM (Usability and information management of the interface)
Learnability
User friendliness
Availability of calculation guidelines
Effective detection of errors and fixing directions
Customisation possibility of inputs
Customisation possibility of outputs (metrics, formats, visualisation, etc.)
Control over the calculation parameters / analysis settings (level of the analysis plan for instance)
IIKB (Integration of intelligent design knowledge-base)
Availability of default input values and calculation parameters
Possibility to compare scenarii
Capacity to make optimisation recommendations
Capacity to verify and justify the compliance to Standards, Certifications and Labels
Possibility to conduct sensitivity analyses
AADC (Accuracy and ability to simulate detailed and complex building components)
Transparency of the method and results
Accuracy (Reliability and Validity) of the results
Quality assurance / Conformity to the standards for Energy and daylighting programs (such as ASHRAE in the US, BBR in Sweden, etc)
Possibility to simulate complex geometries and systems (HVAC systems for instance)
IBM (Interoperability of building modelling)
Ability to handle models from different formats (CAD, RVT, IFC, etc)
Limitations regarding model geometry
Availability of guidelines for modelling the geometry
Export possibilities of the results and data
Amount of work necessary on the geometric model before being able to run the simulation
IBDP (Integrated building design process)
Suitability for early design stage
Adapted use for multidisciplinary project teams (sharing, rights, synchronisation, etc)
Adapted use and complexity by user profile, competence level and stage
Adapted simulation time by stage and use
Continuity between project stages
Instant visualisation of the results and automatic update of the results (Real-time)
Unclassified
Cost (direct short-term, long-term, and associated external (added modelling time, added project tasks, etc.) and internal costs (method, internal training, etc.))
Support (quality, reliability, responsiveness)
Maintenance and updates
Training (by the developer through tutorials, webinars, etc.)

3.2 Organisation into workflow

The following diagram illustrates the process of a typical daylighting simulation undertaken. This process or workflow plays a major role in clarifying methods, responsabilities, aswell as in planning tasks, especially so in a multi-disciplinary context and in complex projects. The steps outlined differ slightly when discussing energy simulations, but the basic principles are consistent. The workflow is representative of daylight modelling within the project; it should not be confused with the workflow for the project, which is much larger and can stretch for a needs analysis to demolition, recycling and reuse of the building and its materials. The diagram displays the different steps in the progression from the forming of environmental goals (in this case related to daylight) until the eventual result is delivered to the architect. The process chart lays out clearly at each stage which participants are involved and what the aim of each stage is for. The process is designed to contribute towards a clear structure with relation to each individual project, at the first stage, called Eco-Design Pre-calculations, the architect and the specialist discuss together the conditions for the modelling. If it is early stage, this may involve representative rooms with various different glazing solutions, while for latter design it may involve the complete building design, various areas of special interest or different floor plans. It is of importance to the project that the architect and specialist concur as to the extent of the model, and how it fits into and answers the design questions posed in the project. The next stages involve production of a functioning model, in the digital design tool, that represents the required parameters. This model is then checked by the specialist and architect together as there may be errors, or changes that have occurred in the timespan since their earlier interaction. It is only at this stage that the simulation can be run. After this, the results are interpreted by the specialist, presented to the architect and, where required, a strategy is decided upon for further simulations. This may involve developing the existing model, or it may involve building a new model to reflect a new scenario.

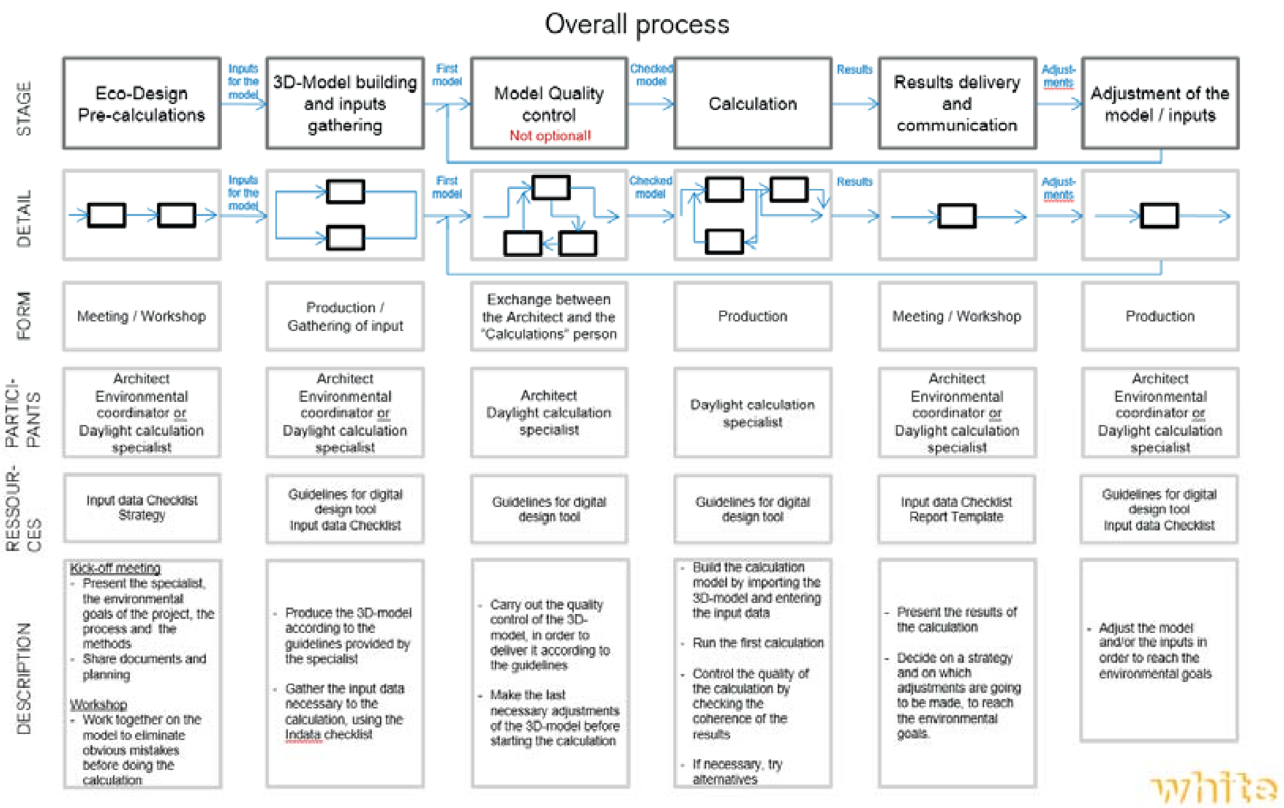

Fig. 2 Daylighting simulation workflow

This approach aligns itself closely with Approach 2 (Scenario approach) in Naboni's interpretation of the different approaches taken by the different practices investigated. There, scenarios are developed and tested with a continuous iterative approach taken towards an optimised solution. However it should be noted that these approaches are not, and should not be treated as mutually exclusive. At the first stage, the initial meeting between the specialist and the architect it is relatively common that they approach the problem first from the 'definition of criteria' approach by applying rules of thumb, and a more experience orientated approach, then to immediately create different scenarios. White also works internally with a research section. There, different research projects have resulted in guidelines for energy efficient design, atria design and other related topics.

4. Discussion

Criteria that are additional to Attia's categories that were identified in the evaluation are cost, maintenance and updates, support and training. These criteria differ from the other selection criteria in that they are connected to company level decision making process, and relate to economic, strategic and quality control indicators.

Increasingly BPS tools are being designed for conducting calculations at early stage design in order to have the highest impact on the design. The results indicate however that is it difficult to select a tool which can be used with confidence throughout the design, both in early, late and final design stages. The ability to visualise the results is increasingly important as the calculation point moves towards the early stage. As Hamza and DeWilde state an effective visualisation of the results and data plays a key role in the interaction between stakeholders, and thus on the impact of calculations on decision making [10].

With regard to workflow, the approach that White has taken to how it integrates digital design into its project workflow is comparable to the approach described by Naboni as the scenario based approach. According to Naboni this approach is prevalent at organisations such as Fosters + Partners, Henning Larsen and LMN Architects. A relevant prerequisite for this approach is the ability of the project team and the specialist to work side-by-side. This dovetails with White's aim to spread the use of BPS tools from a small team of specialists to a more outspread organisation working in different offices. This means that the other offices have more contact with specialists and thereby more access to the use of BPS tools. The ability to experiment with scenario based design requires good communication abilities between the different parties and a functioning structure to ensure that this happens.

An interesting discussion point raised from the research, would be the impact on the process of a change in the approach taken. Increasing computing power due to cloud solutions allows greater use of parametric design then was previously the case. Another part of White Arkitekter, DSearch, works intensively with parametric design and form finding. It would be an interesting, and potentially informative, exercise to compare their workflow process with that used in this case.

Finally, as mentioned previously, the recent developments allowing to perform calculations in the geometrical model through plug-ins, are expected to lead to increasing friction over ownership of the procedure and the model. This is without doubt another very interesting subject to examine further.

5. Conclusion

White has carried out its own evaluation of a BPS tool as there does not currently exist an independent comparison model of the different BPS tools available. This paper shows that the selection of an appropriate BPS tool for a multi-disciplinary architectural practice broadly follows BPS tool selection criteria identified by Attia. Criteria related to costs, support and maintenance also play a role.

The integration of BPS tools into projects results in a workflow which reflects a scenario by scenario approach as described by Naboni. A future move towards a more parametric approach will therefore require that the workflow is adjusted in order to reflect the differences in approach.

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Investment vs. subsequent costs - the significance of occupancy costs in real estate life-cycle

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Summary

Occupancy costs represent a substantial proportion of the expenditures incurring over the life-cycle of real estate and play a decisive role to ensure economical sustainability. Based on the evaluation of empirical data, the main objective of the current approach is to examine the monetary significance of occupancy costs in comparison to construction costs for various types of facilities. Therefore, the temporal progression of these cost types is illustrated and the point in time when occupancy costs exceed construction costs is identified. A change of value over time is considered by application of the net present value. To reduce uncertainty, scenarios with discount rates of 1.5% and 5.5% are examined. The main findings reveal a wide range of possible results. Occupancy costs exceed construction costs after between 20 years (care retirement homes) and 42 years (church buildings) applying a discount rate of 1.5%. For a discount rate of 5.5%, an intersection can be identified after between 36 and more than 250 years. Though the results are highly depending on the employed discount rates, the significance of occupancy costs in the life-cycle of real estate is verified in the current study.

Keywords: Comparison, construction costs, life-cycle costs, subsequent costs, occupancy costs

1. Introduction

To ensure economical sustainability it is a crucial task for all participants involved in the planning process to determine all regularly and irregularly incurring costs (life-cycle costs) associated with a building from the beginning of the planning over the construction (investment costs) and the occupancy until the reclamation or demolition (subsequent costs). Consequently, cost-benefit analysis for potential alternatives can be developed and implemented at the earliest possible stage of the planning process and costs can be monitored and controlled during the operation of real estate in an iterative process. Thereby, occupancy costs represent a significant amount of financial expenditures over a buildings' life-cycle.

The current approach examines the significance of occupancy costs in comparison to construction costs for various types of facilities based on the evaluation of empirical data. Therefore, suitable observations are selected out of a data pool including occupancy cost data of more than 250 building projects and construction cost data of about 2,500 building projects in Germany. Empirical methods are employed for description of the data and evaluation. The proportion of occupancy costs to construction costs is determined and the temporal progression including the point of intersection between these cost types is illustrated. In order to consider the change of a current value over time, the net present value is applied as a method to discount costs incurring in the future to a present value. Individual parameters are varied in scenarios to analyse the robustness of the developed models.

The main objectives of the current study can be summarised as follows:

- Examination of occupancy costs' proportion to construction costs.
- Illustration of the temporal progression of these cost types over a time period.
- Determination of the point in time when occupancy costs exceed construction costs.
- Consideration of a change of value over time for costs incurring in the future.
- Identification of robustness by variation of input parameters.

The study is structured as follows: The theoretical basis of the study including an introduction of variables is outlined in Chapter 2. Furthermore, the data sample employed for the implementation of the study is presented including descriptive statistics. Chapter 3 contains a presentation of detailed results for an exemplary type of facility. Moreover, results for the total sample and all examined types of facilities are outlined. Main findings of the study and a conclusion are summarised in Chapter 4.

2. Methodology

In the current study, the proportion of occupancy costs to construction costs is determined and the temporal progression including the point of intersection between these cost types is illustrated. Therefore, the net present value is applied as a method to consider the present value of occupancy costs incurring in the future. The net present value can be used to determine the life-cycle costs of buildings and can serve as a tool for decision-making [1]. Assuming a decrease of a current value in the future [2], the method examines costs and values over a number of time periods and resolves them to equivalent present day costs and values by a certain discount rate [3]. The net present value (NPV) is explained by the generalised relationship illustrated in Equation 1.

$$\mathrm{NPV}(i,n) = \sum_{t=0}^{n} \frac{R_t}{(1+i)^t} \tag{1}$$

where
i is the discount rate,
n is the total number of time periods,
t is the time of the cash flow, and
R_t is the net cash flow.

Consequently, the discounted value of occupancy costs over a number of time periods is compared to the construction costs in the current study. Various variables included as parameters in the analysis are described in Table 1. Besides the construction cost and operating cost data presented in detail in Tables 2 and 3, the repair costs as part of the occupancy costs are determined as percentage of the construction costs according to BBSR [4]. Repair costs are calculated separately for construction works with 1.2% and services ranging between 0.725% and 1.32% according to the type of facility.

Table 1: Analysis parameters

Variable		Value(s)	Source
Constr. costs	Construction works	cf. Table 2	BKI [5]
	Services	cf. Table 2	BKI [5]
Occupancy costs	Operating costs	cf. Table 3	Data sample
	Repair: Constr. works	% of costs for constr. works: 1.2 %	BNB [6]
	Repair: Services	% of costs for services (acc. to facility type): 0.725% to 1.32%	BBSR [4]
Escalation rate	General esc. rate	2 %	BNB [6]
	Energy supply	4 %	BNB [6]
Discount rate	Scenario 1	1.5 %	UBA [7]
	Scenario 2	5.5 %	BNB [6]

Under consideration of a change in price level over time, a general escalation rate for operating and repair costs of 2% and an escalation rate for energy supply of 4% according to BNB [6] is used in the calculations. As described by Boussabaine [8], uncertainty and risk in the determination of life-cycle costs can be reduced by application of scenarios. Therefore, the discount rate for calculation of the net present value of the occupancy costs is varied in scenarios employing 1.5% (Scenario 1) according to UBA [7] and 5.5% (Scenario 2) according to BNB [6].

As presented in ISO 15686-5 [9], it can be beneficial to model the uncertainty using statistical techniques. Similar to Monte Carlo methods, the uncertainty of the calculation is taken into account by application of a range of construction and occupancy cost indicators as basis for the calculation of the temporal progression and the point of intersection of these cost types. Therefore, the net present value is calculated for all possible combinations of the available construction cost observations and the available occupancy cost observations.

The current approach employs empirical construction cost data of 620 observations selected by the type of facility out of more than 2,500 observations in total provided by the Cost Information Centre of the German Chamber of Architects (BKI) [5]. Construction costs are adjusted to 1st quarter 2015 prices including German VAT and are normalised to cost indicators by applying the gross external floor area (GEFA) according to DIN 277-1 [10] as reference area. The employed data is differentiated in both, cost indicators for construction works and cost indicators for services according to the cost structure of DIN 276-1 [11] for all 11 examined types of facilities and is presented in detail including descriptive statistics in Table 2.

Furthermore, the current study is employing operating cost data consisting of 231 observations selected out of a total sample of more than 250 observations as a basis. The data collection was conducted in the years 2008 until 2014 in Germany and includes data provided by 25 project partners. The cost data were monitored over at least 1 up to 5 years, depending on the availability of data from the particular project partner.

Table 2: Descriptive statistics for construction costs

Construction costs (Euro/m² GEFA)[1]		Mean	St. dev.	Min.	Lower quartile	Median	Upper quartile	Max.	No. obs.
Total sample	Constr. works	1,213	383	191	985	1,168	1,390	4,269	620
	Services	356	233	2	224	300	420	2,458	
Care retirem. home	Constr. works	931	206	568	788	941	1,046	1,505	26
	Services	404	128	225	289	373	533	639	
Church building	Constr. works	2,133	946	950	1,488	1,897	2,611	4,269	10
	Services	325	136	210	216	259	424	614	
Community hall	Constr. works	1,284	312	720	1,056	1,238	1,489	2,320	62
	Services	299	145	112	196	284	394	802	
Fire department	Constr. works	1,011	243	607	823	964	1,181	1,570	37
	Services	257	133	70	165	238	292	725	
Kindergarten	Constr. works	1,197	304	580	1,019	1,169	1,343	2,858	146
	Services	269	109	88	184	254	334	761	
Library	Constr. works	1,115	243	910	928	959	1,381	1,395	5
	Services	313	112	209	215	269	433	445	
Municipal building	Constr. works	1,162	344	365	895	1,109	1,326	2,145	121
	Services	383	267	2	228	334	457	2,458	
Research / Teach.	Constr. works	1,318	212	952	1,163	1,297	1,438	1,757	27
	Services	819	421	284	479	836	1,005	1,932	
School facility	Constr. works	1,194	297	518	1,008	1,158	1,371	2,170	96
	Services	341	124	43	268	324	398	756	
Sport facility	Constr. works	1,304	508	191	1,039	1,269	1,436	4,123	86
	Services	413	279	9	237	343	504	1,684	
Town hall	Constr. works	1,510	167	1,265	1,338	1,570	1,622	1,635	4
	Services	397	156	207	250	396	543	587	

[1] Cost indicators are adjusted to 1st quarter 2015 prices including VAT

The operating cost indicators presented in Table 3 are adjusted to 1st quarter 2015 prices including German VAT using the gross external floor area as reference unit. Operating and repair costs included in the current study are defined by the cost structure given in DIN 18960 [12].

Table 3: Descriptive statistics for operating costs

Operating costs (Euro/m² GEFA*a)[1]	Mean	Standard deviation	Minimum	Lower quartile	Median	Upper quartile	Maximum	No. obs.
Total sample	38.83	16.81	4.76	26.50	36.60	48.12	97.80	231
Care retirement home	44.54	18.63	22.94	26.61	45.26	66.04	72.11	13
Church building	16.29	6.07	4.76	12.25	14.64	20.18	27.03	13
Community hall	19.74	3.57	14.76	16.07	20.86	22.86	23.06	5
Fire department	24.18	9.67	12.97	15.27	22.07	34.14	35.12	5
Kindergarten	44.25	17.08	8.57	33.70	43.10	53.74	97.80	122
Library	26.96	4.56	21.05	22.23	27.80	30.85	31.19	4
Municipal building	25.56	10.37	6.25	19.49	26.39	33.88	40.90	9
Research / Teaching	34.13	14.91	20.15	24.38	29.03	39.12	75.82	12
School facility	36.63	10.89	26.13	29.68	33.89	37.86	68.73	22
Sport facility	41.82	9.86	26.28	33.11	41.04	48.18	63.00	19
Town hall	30.42	7.71	23.45	25.53	26.69	32.97	45.85	7

[1] Cost indicators are adjusted to 1st quarter 2015 prices including VAT

3. Results

3.1 Detailed results for kindergarten facilities

Based on the empirical data and the analysis parameters described in Chapter 2, the progression of the occupancy costs over time is developed applying the net present value. Furthermore, the point of intersection with the construction cost data is calculated and illustrated for all 11 types of facilities and the total sample. The temporal progression and the point of intersection is calculated for all possible combinations of the available construction and occupancy cost observations. For instance, this results in 17,812 possible combinations for kindergarten facilities being calculated (146 construction cost observations multiplied by 122 operating cost observations). Due to complexity of calculation, the maximum observation period is set to 250 years for all types of facilities.

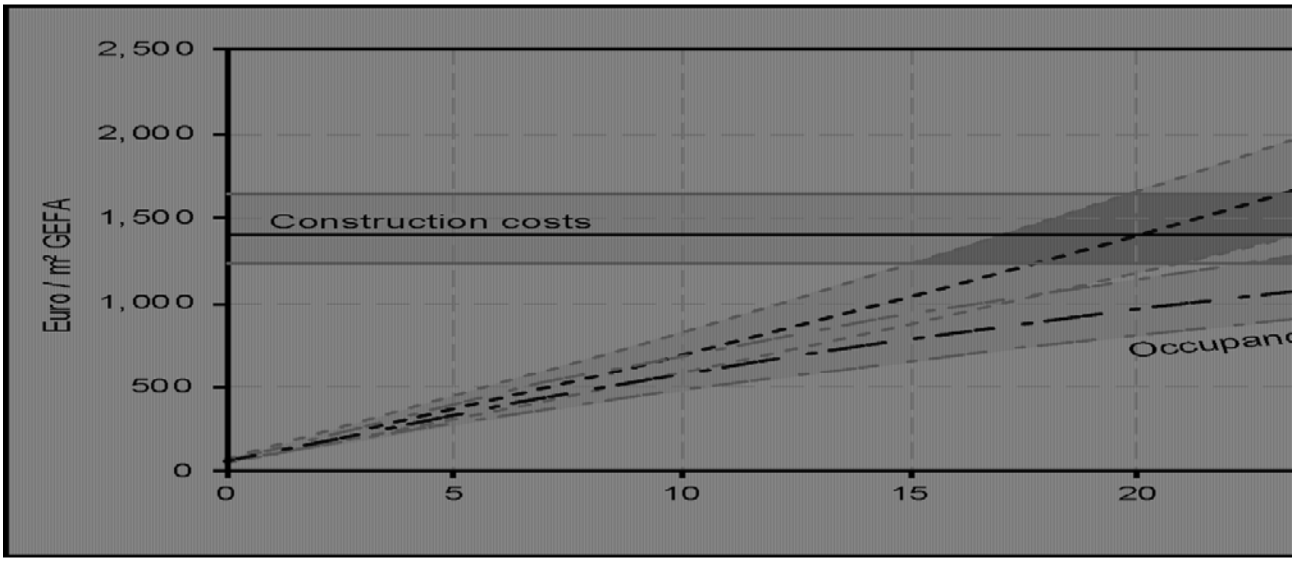

Figure 1: Occupancy costs vs. construction costs for kindergarten facilities

Figure 1 illustrates the temporal progression of the net present value of the occupancy costs in comparison to the construction costs for kindergarten facilities. As outlined in Chapter 2, scenarios for discount rates of both, 1.5% (Scenario 1) and 5.5% (Scenario 2) are presented simultaneously in the diagram. Among the median value, the lower and upper quartiles for all calculated observations is given for both, construction and occupancy costs. For reasons of comprehensibility, the illustrated temporal progression is limited to an observation period of 50 years for kindergarten facilities, though the progression is calculated over 250 years in total.

Furthermore, the point of intersection for the net present value of occupancy costs exceeding the construction costs monetarily can be identified in the diagram. With otherwise constant variables of the general escalation rate (2%) and the escalation rate for energy supply (4%), a significant influence of the discount rate on the progression of the occupancy costs' net present value is indicated. The median value of occupancy costs exceeds the median value of construction costs after about 21 years for Scenario 1 and after about 38 years for Scenario 2. The results for further types of facilities are summarised in Chapter 3.2 for Scenario 1 (1.5% discount rate) and in Chapter 3.3 for Scenario 2 (5.5% discount rate).

3.2 Summarised results for Scenario 1

The points of intersection between the net present value of the occupancy costs and the construction costs is determined by calculation as described in Chapter 2 of the current study, resulting in a point in time when occupancy costs exceed the construction costs monetarily. The results of the analysis for Scenario 1 with a discount rate of 1.5% according to UBA [7] are presented in Table 4, differentiating the total sample and the different types of facilities. Furthermore, the annual shares of occupancy costs on construction costs are given. Besides, the median values, the minimum and maximum, as well as the lower and upper quartiles are illustrated in Table 4.

Table 4: Points of intersection between occupancy and construction costs (Scenario 2)

Type of facility		Minimum	Lower quartile	Median	Upper quartile	Maximum	No. obs.
Total sample	Years	1.8	19.0	24.0	29.7	68.5	143,221
	per Year	1.5%	3.4%	4.2%	5.3%	56.1%	
Care retirement home	Years	8.6	15.4	20.1	25.1	35.0	338
	per Year	2.9%	4.0%	5.0%	6.5%	11.6%	
Church building	Years	23.0	36.3	42.0	48.0	64.6	130
	per Year	1.5%	2.1%	2.4%	2.8%	4.3%	
Community hall	Years	21.7	29.5	32.8	36.2	45.7	310
	per Year	2.2%	2.8%	3.0%	3.4%	4.6%	
Fire department	Years	14.1	21.3	26.7	31.8	41.9	185
	per Year	2.4%	3.1%	3.7%	4.7%	7.1%	
Kindergarten	Years	5.9	16.7	20.5	25.1	56.4	17,812
	per Year	1.8%	4.0%	4.9%	6.0%	16.9%	
Library	Years	21.5	24.0	27.4	29.8	34.2	20
	per Year	2.9%	3.4%	3.6%	4.2%	4.6%	
Municipal building	Years	11.9	23.5	28.2	33.9	56.6	1,089
	per Year	1.8%	3.0%	3.5%	4.3%	8.4%	
Research / Teaching	Years	13.4	26.3	30.8	35.2	46.8	324
	per Year	2.1%	2.8%	3.2%	3.8%	7.5%	
School facility	Years	7.3	21.4	24.7	27.4	37.1	2,112
	per Year	2.7%	3.7%	4.0%	4.7%	13.8%	
Sport facility	Years	8.0	20.0	24.0	27.0	49.0	1,596
	per Year	2.0%	3.7%	4.3%	5.1%	12.3%	
Town hall	Years	21.3	28.0	30.5	32.8	35.2	28
	per Year	2.8%	3.1%	3.3%	3.6%	4.7%	

The total sample with its 143,221 combined observations reveals a median value of 24 years when occupancy costs exceed the construction costs monetarily. According to the median values, the intersection of the costs types is ranging between 20 years for care retirement homes and 42 years for church buildings applying a discount rate of 1.5% for the occupancy costs' net present value. Accordingly, the median values of the annual share of occupancy costs on construction costs vary between 2.4% and 5.0%. Referring to the minimum and maximum values, occupancy costs exceed construction costs after between 6 years for kindergartens (maximum annual share of 16.9%) and 65 years for church buildings (minimum annual share of 1.5%).

The presented results are illustrated by boxplots including the median value as well as the upper and lower quartiles for the total sample and the 11 types of facilities in Figure 2 (years after which occupancy costs exceed construction costs) and Figure 3 (annual share of occupancy costs on construction costs).

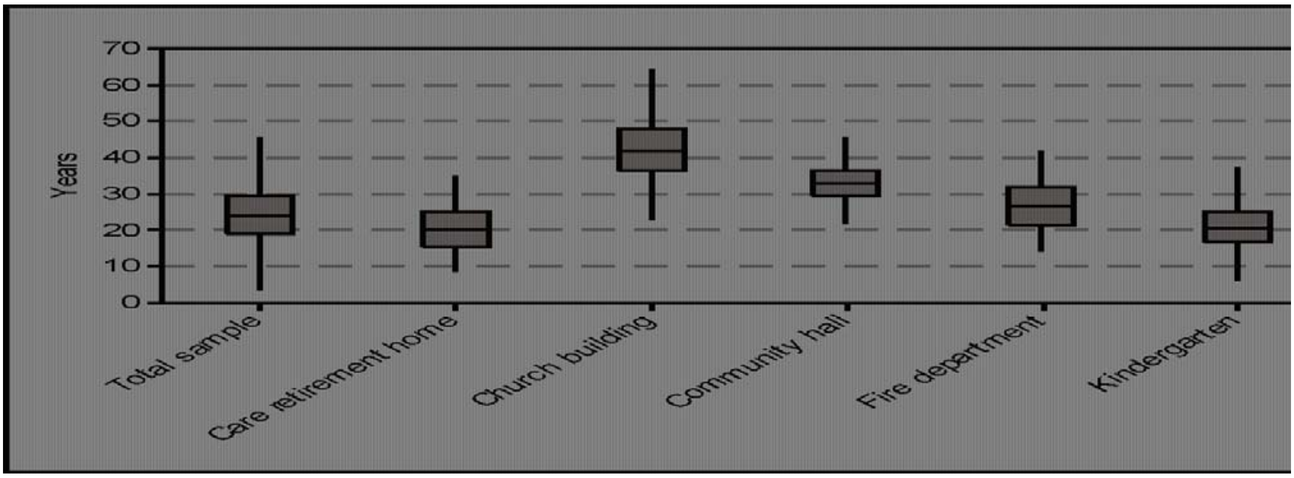

Figure 2: Boxplots of years when occupancy costs exceed construction costs (Scenario 1)

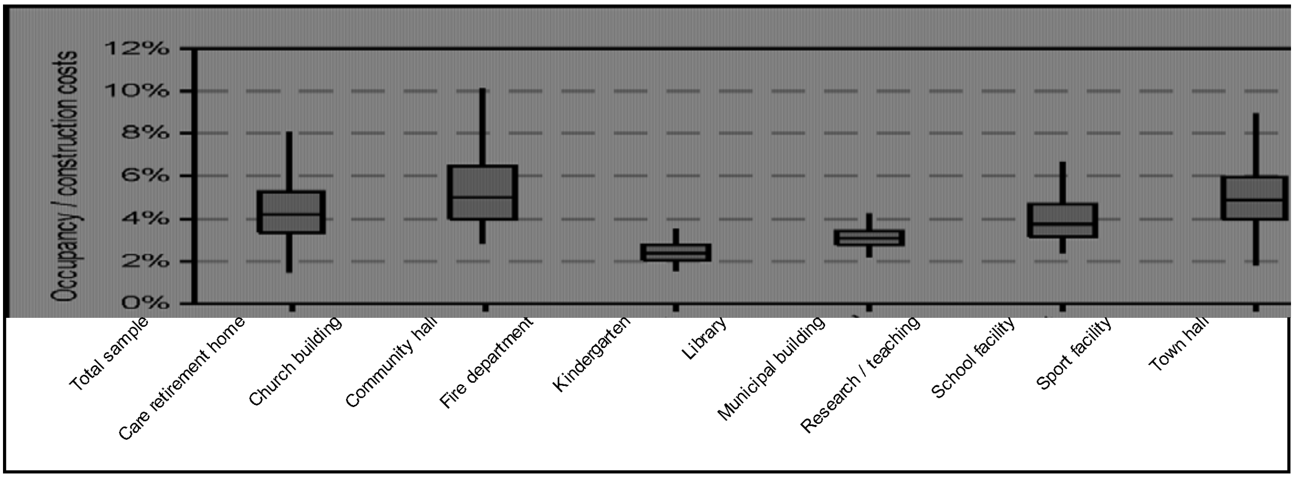

Figure 3: Boxplots of annual share of occupancy costs on construction costs (Scenario 1)

3.3 Summarised results for Scenario 2

The results for Scenario 2 with a discount rate of 5.5% as described by BNB [6] are presented in Table 5. Therefore, the points of intersection between the occupancy costs' net present values and the construction costs are calculated, resulting in a point in time when the occupancy costs exceed the construction costs monetarily. Median values, minimum and maximum values, as well as lower and upper quartiles are given for the total sample and the different types of facilities. As described in Chapter 3.1, the maximum period for calculation is set to 250 years for all types of facilities. If the result for a single observation exceeds the maximum period, the value '> 250 years' is employed for further utilisation.

A median value of about 53 years before occupancy costs exceed the construction costs monetarily is revealed for the total sample with its 143,221 combined observations. According to the median values, the intersection of the costs types is ranging between 36 years for care retirement homes and a value greater than 250 years for church buildings applying a discount rate of 5.5% for the calculation of the net present value of the occupancy costs. Accordingly, the median values of the annual share of occupancy costs on construction costs vary between a value smaller than 0.4% and 2.8% for these facility types. Referring to the minimum values, occupancy costs exceed construction costs after 7 years for kindergartens (maximum annual share of 14.6%). The maximum values for all types of facilities exceed the threshold of 250 years.

Table 5: Points of intersection between occupancy and construction costs (Scenario 2)

Type of facility		Minimum	Lower quartile	Median	Upper quartile	Maximum	No. obs.
Total sample	Years	1.9	32.7	52.9	110.8	> 250	143,221
	per Year	< 0.4%	0.9%	1.9%	3.1%	53.0%	
Care retirement home	Years	10.7	23.2	35.8	56.7	> 250	338
	per Year	< 0.4%	1.8%	2.8%	4.3%	9.4%	
Church building	Years	44.7	> 250	> 250	> 250	> 250	130
	per Year	< 0.4%	< 0.4%	< 0.4%	< 0.4%	2.2%	
Community hall	Years	41.6	96.2	234.0	> 250	> 250	310
	per Year	< 0.4%	< 0.4%	0.4%	1.0%	2.4%	
Fire department	Years	20.2	39.5	67.8	142.0	> 250	185
	per Year	< 0.4%	0.7%	1.5%	2.5%	5.0%	
Kindergarten	Years	6.8	26.4	37.8	60.5	> 250	17,812
	per Year	< 0.4%	1.7%	2.6%	3.8%	14.6%	
Library	Years	41.1	50.4	71.4	102.9	> 250	20
	per Year	< 0.4%	1.0%	1.4%	2.0%	2.4%	
Municipal building	Years	16.0	49.1	85.7	> 250	> 250	1,089
	per Year	< 0.4%	< 0.4%	1.2%	2.0%	6.3%	
Research / Teaching	Years	18.6	62.5	108.0	> 250	> 250	324
	per Year	< 0.4%	< 0.4%	0.9%	1.6%	5.4%	
School facility	Years	8.7	41.3	58.9	83.9	> 250	2,112
	per Year	< 0.4%	1.2%	1.7%	2.4%	11.5%	
Sport facility	Years	10.0	35.0	51.0	81.0	> 250	1,596
	per Year	< 0.4%	1.2%	1.9%	2.8%	10.1%	
Town hall	Years	39.7	83.1	132.0	246.6	> 250	28
	per Year	< 0.4%	0.4%	0.8%	1.2%	2.5%	

The boxplots in Figures 4 and 5 illustrate the presented results including the median as well as the upper and lower quartiles for the total sample and the 11 types of facilities. Thereby, the years when occupancy costs exceed the construction costs (Figure 4) and the annual share of occupancy costs on construction costs (Figure 5) are visualised.

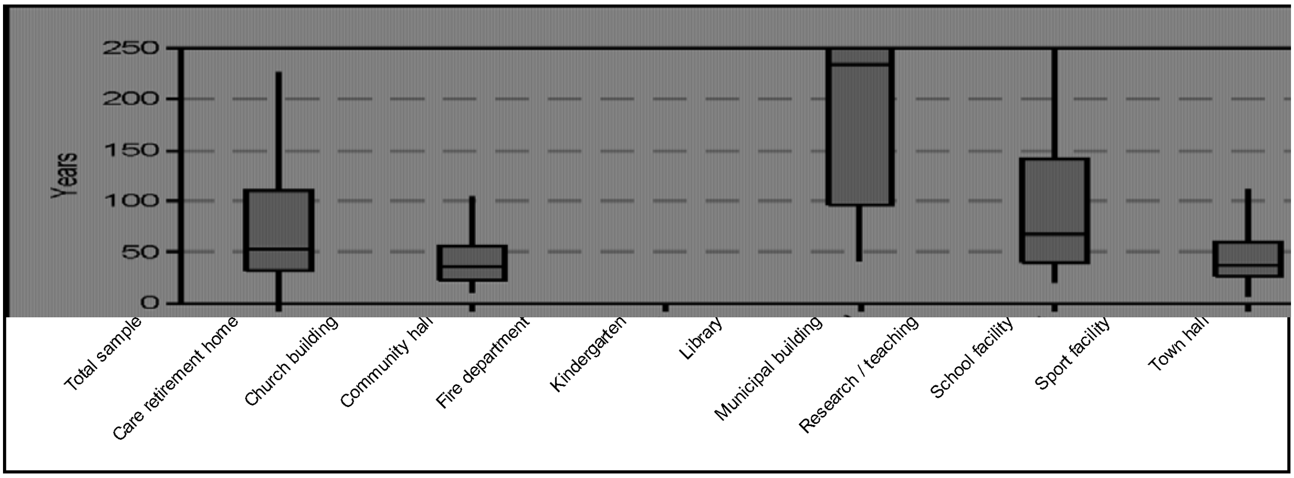

Figure 4: Boxplots of years when occupancy costs exceed construction costs (Scenario 2)

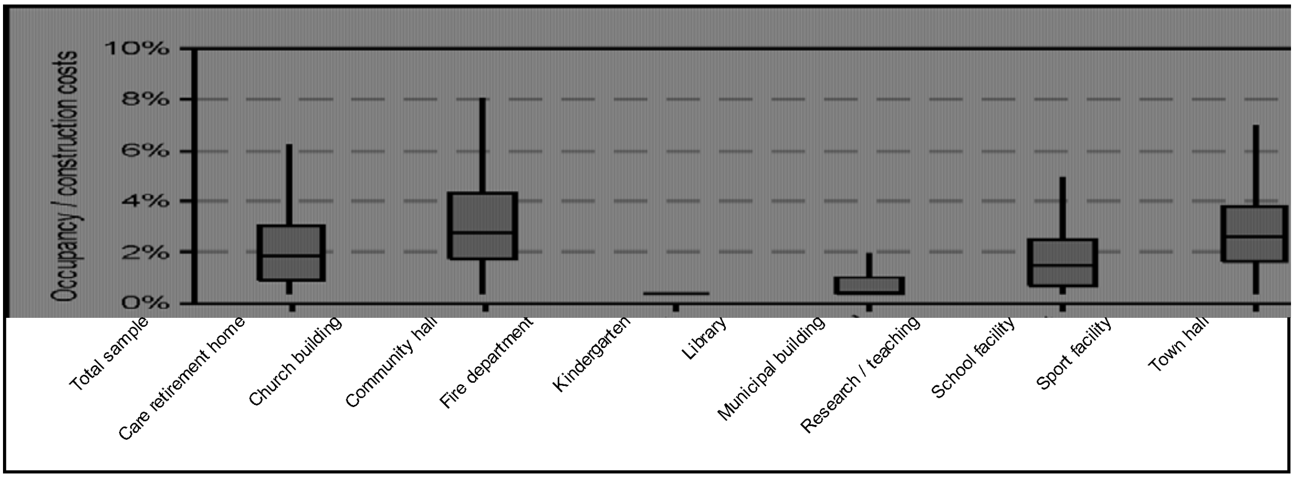

Figure 5: Boxplots of annual share of occupancy costs on construction costs (Scenario 2)

4. Discussion and Conclusion

Occupancy costs represent a significant amount of financial expenditures over a buildings' life-cycle and play a decisive role to ensure economical sustainability. Therefore, the main objective of the current study is to examine the significance of occupancy costs in comparison to construction costs. Based on an evaluation of empirical data, the proportion of occupancy costs to construction costs is determined, the temporal progression of these cost types is illustrated, and the point in time when occupancy costs exceed construction costs is identified. The change of value over time is considered by application of the net present value on costs incurring in the future. Robustness of the developed models is analysed by variation of parameters in scenarios. The uncertainty of calculation is taken into account by application of a range of observations of both, construction and occupancy costs as data basis.

To reduce uncertainty and risk, scenarios with different discount rates for the calculation of the net present value are developed. With discount rates of 1.5% (Scenario 1) and 5.5% (Scenario 2), two extreme scenarios are examined in order to demonstrate a wide range of possible results. The points in time when occupancy costs exceed the construction costs range between 20 years (care retirement homes) and 42 years (church buildings) applying a discount rate of 1.5%. Accordingly, the annual share of occupancy costs on construction costs varies between 2.4% and 5.0%. For Scenario 2 (5.5% discount rate), an intersection between the cost types can be identified ranging between 36 years for care retirement homes and more than 250 years for church buildings. The annual shares of occupancy costs on construction costs vary between less than 0.4% (church buildings) and 2.8% (care retirement home).

Despite the fact that the results are highly depending on the discount rates for the calculation of the net present value, the significance of occupancy costs in the life-cycle of real estate can be verified in the current study. Due to a limited number of observations for some of the types of facilities included, the quality of the presented results may be improved by extension of the data sample. Likewise, further approaches may include additional types of facilities (e.g. laboratories, industrial buildings, medical buildings, health service facilities) for an analysis. In the current study, repair costs are determined by percentage of construction costs due to a limited number of observations including repair costs in the sample. Consequently, future research may extend its focus on regularly and irregularly incurring repair costs as a substantial part of occupancy costs.

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LCA, EPD and Labels – How to Select Green Building Products?

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Summary

Environmental labels Type III according to ISO 14025 (Environmental Product Declaration/EPD) and labels Type I according to ISO 14024 (Environmental labels) specify criteria to support the selection of sustainable building products. Although industry and politicians prefer environmental declarations, environmental labels demonstrate their greater suitability in the tendering process: They provide the procurement bodies (both private and public) with sustainability criteria that reflect public concensus as well as the corresponding proofs. This is the finding of a current research study that provides public authorities with appropriate procurement guidelines.

Keywords: EPD, Labels, LCA, Market Change, Green Public Procurement

1. Introduction

A new legal position relating to public procurement and the award of building contracts has come into being since the introduction of Directive 2014/24/EU of 26th February 2014 [1]. This so-called "contract award directive" or "classical directive" encompasses public building contracts as well as supply and services contracts for public authorities. This new ruling, which replaces the former regulations for public procurement from 2004, enables the contracting authority to use the public procurement process to support common social and environmental objectives (innovative, ecological, social etc.) to an even greater extent. Regarding the aims of this new directive, it is stated in the preliminary remarks (74) of Directive 2014/24/EU: "The technical specifications drawn up by public purchasers need to allow public procurement to be open to competition as well as to achieve objectives of sustainability. To that end, it should be possible to submit tenders that reflect the (…) technical specifications in the marketplace, including those drawn up on the basis of performance criteria linked to the life cycle and the sustainability of the production process of the works, supplies and services". Preliminary remark (75) specifies that in order to achieve these objectives it should be possible for contracting authorities to refer, above all, to (preferably multinational) eco-labels and other labels in the procurement process.

The EU Construction Products Regulation No. 305/2011 [2] extends the requirements for the CE-marking. In the future, manufacturers of construction products must draw up a declaration of performance relating to the essential characteristics of the product, and not as formerly the case just "the safety of buildings and other construction works" but also "health, durability, energy economy, protection of the environment and other important aspects in the public interest". Manufacturers

are no longer permitted to make additional (marketing) claims about the performance of a construction product other than those contained in the declaration of performance. Preliminary remark (56) states in concrete terms that “For the assessment of the sustainable use of resources and of the impact of construction works on the environment Environmental Product Declarations should be used when available”.
In annex 1 “Basic requirements for construction works” of EU Construction Products Regulation No. 305/2011, the objectives and the corresponding essential characteristics are defined. For example, under the heading “Hygiene, health and the environment” it is stated that: “The construction works must be designed and built in such a way that they will, throughout their life cycle, not be a threat to the hygiene or health and safety of workers, occupants or neighbours, nor have an exceedingly high impact, over their entire life cycle, on the environmental quality or on the climate during their construction, use and demolition, in particular as a result of any of the following: a) the giving-off of toxic gas; b) the emissions of dangerous substances, volatile organic compounds (VOC), greenhouse gases or dangerous particles into indoor or outdoor air; c) the emission of dangerous radiation; d) the release of dangerous substances into ground water, marine waters, surface waters or soil; (...)“
In addition to other requirements, in annex 1 under the heading “Sustainable use of natural resources” it is stated that: “The construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and in particular ensure the following: a) reuse or recyclability of the construction works, their materials and parts after demolition; b) durability of the construction works; c) use of environmentally compatible raw and secondary materials in the construction works.“

If, in the near future, contracting/procurement bodies – not only public authorities – across the whole of Europe are legally bound to include sustainability objectives in their invitations for tenders it is absolutely essential

a) to clarify in each particular case which sustainability objectives are to be met by each of the purchased construction products and
b) to be completely clear about how, and through which proofs, the fulfilment of these requirements can be verified.

It is necessary therefore to highlight the various proofs which are currently available and which already play a certain role in the tendering process and which will probably serve as a basis for the harmonized regulations for the implementation of the EU Construction Products Regulation. In addition to national mandatory regulations, such as the DIBT accreditation assessment in Germany or the French VOC emissions regulations in accordance with "Décret n° 2011-321", or declaration regulations in safety data sheets e.g. in accordance with REACH – these include, above all, the voluntary eco-labels. It is particularly important to differentiate between two types:

1. Environmental quality labels (Labels), Type I Environmental labels according to ISO 14024
2. Environmental declarations (EPD), Type III Environmental labels according to ISO 14025

It is the aim of this presentation to elaborate upon the contribution that environmental declarations Type III and environmental quality labels Type I can play in the introduction of sustainability objectives in the construction tendering/procurement process; to show the results of a current research study of natureplus, funded by German Government, to compare Labels Type I from all over Europe in their suitability to Green Public Procurement (GPP); to explain their role in raising the market share of sustainable construction products through the ‘pull-effect’ of an increased public and private demand for these products.

2. Methodology

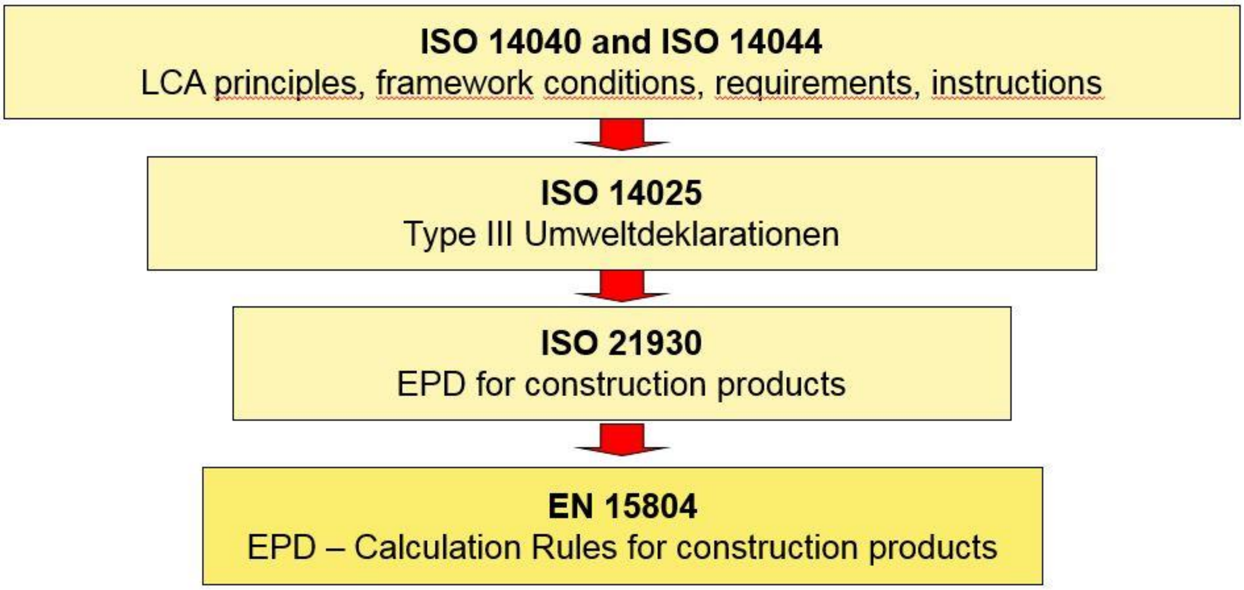
This presentation is primarily based on the findings of two projects conducted by natureplus e.V.: On 28th May 2015 a specialist conference was held by natureplus e.V. in Neckargemünd near Heidelberg, Germany under the heading "LCA, EPD and Labels - Do They Help to Compare the Ecological Impact of Building Materials?" Eleven representatives from seven countries discussed the practical difficulties encountered in making comparable product evaluations and the resulting lack of clear consumer guidance posed by current life-cycle assessments and their presentation and publication in various environmental declarations and a limited number of labels. From the discussions it became clear that the only possible solution was a collaboration between labels and declarations and a standardization of assessment methods and standards.

In September 2015 natureplus e.V. completed a research project “Comparison of European labels incorporating sustainability requirements for building materials” [3] which had the aim of developing tools for the introduction of sustainability requirements for building products in the construction tendering process (invitations for tenders). Based on an analysis of 21 environmental labels from 8 European countries, the project identified 62 sustainability criteria for building products that were appraised as suitable for the tendering process. Based on these criteria, 6 tendering process aids for building product groups relevant to interior applications were developed.

3. Results

3.1 LCA do not enable a comparison of products

Life Cycle Assessments (LCA) play an especially important role as they aim to comprehensively determine the environmental impact of a product. They do not only highlight individual environmental impacts or those characteristics which are especially positive for the environment, as is normally the case for Eco-labels, but include numerical data on the total impact (where possible) of the product over its whole life-cycle – from resource extraction, manufacture and use to its disposal – in terms of the primary energy consumption, CO2 emissions and other environmentally relevant factors. The LCA therefore provides us with a scientifically recognized tool for evaluating products.



The data gathered in the preparation of a LCA are published in a particular format within the framework of an EPD. This format is regulated by a whole series of rules and standards (see Fig.1).

Despite these regulations it is still not possible to make direct comparisons between an EPD and the LCA upon which it is based. Although they contain a whole range of information, which, above all, enable the manufacturer to identify weaknesses in its production process, they do not contain an evaluation of the assessed product and furthermore do not enable a direct comparison of multiple comparable products.

3.2 EPDs provide little construction product selection guidance

EPDs are currently favoured by politicians and the large building product manufacturers over environmental labels. The most important arguments are the supposed "neutrality" of a purely number based representation and the assessment of the whole life cycle by an LCA rather than the accentuation of individual product characteristics. It is apparently also not just the characteristics of individual building products which are of interest but the building as a whole. Based on these arguments, products with LCA-based EPD are granted a monopoly position for inclusion in (both state and private) building evaluation systems at the national level (above all in Germany, UK and France) as well as at the EU level but also as a proof of performance for CE-marking. According to a state Dekret, in Belgium and France a company is only allowed to use environmental arguments in its advertising when it can provide an EPD for the product.
This is despite the fact that an EPD does not, as such, contain any evaluative statements that might, for instance, indicate that the product exhibits a particularly good ecological performance. An EPD is simply the sober calculation of data on the environmental impact. It is even expressly desired that an EPD documents the poor environmental characteristics of a product. A positive environmental argument can only be made using an EPD in such a manner that a particular parameter – such as the energy consumption in manufacturing – is lower than that of a competitor. Such a comparison is however, as shall be shown, not desired by industry and is even impeded by national egotism. Therefore the use of an EPD as an advertising argument for a product is, for all intents and purposes, systematically ruled out and it must be regarded as unfair and anti-competitive advertising. Nevertheless numerous European governments are currently promoting this misuse of EPDs.

Industry also has a great interest in ensuring that state bodies and the market favour environmental declarations over eco-labels. The most important argument for them, although one that is rarely openly mentioned, is the restriction of competition in the field of environmental issues: Where an environmental label will single out a product from among its competitors, a declaration is not bound by the fulfilment of benchmarks and actually constitutes an obstacle to product comparison. It is, above all, the large industrial trade associations such as the German Building Materials Association (BBS) which are so disparaging about certifications conducted by environmental labels and, at the same time, recommend the introduction of EPDs to their members.
In a BBS guideline on "sustainable evaluation of structures" express reference is made to the competitive situation as an argument for EPDs and against labels: "The use of environmental labels, for instance the Blaue Engel or the EU-Ecolabel, for building products may, due to the limited scope, possibly lead to misinformation and distortions of competition." Instead the industry associations – with financial support from the German Federal Government – produced numerous generic EPDs for the most important mineral-based building products. These 'sector EPDs' deliberately grouped together various production facilities with completely different operating conditions

in order to simulate the widest range of environmental conditions. From this a mean value was calculated as a generic EPD.
The stated goal of industry was to then use this meaningless mean value to supply proof of the sustainability characteristics which were demanded by the Government and the market. This would save the money that would need to be spent on a detailed analysis of each of the local production site conditions. It would also exclude any environmental competition amongst the companies as they all had to supply the same figures. This is exactly how the industry initially asserted itself: Both the various systems of building evaluation such as DGNB and BNB, breeam or LEED as well as the contract award directive 2014/24/EU confirm that these generic EPDs are accepted as proof. At this level the EPD, as a tool for building product selection guidance, has already bowed out.

However, even if a company did not shy away from this expense and produced a specific EPD for a particular type of production, this is not worth much in terms of the utility of this declaration as tool for guidance: A great deal of expertise is required to interpret the bare numerical values in an EPD. Many of the characteristics of greatest importance to the consumer and construction professional, such as an emissions test or the use of certain harmful substances, are not contained within the EPD. An additional limitation – despite all the available official standards – is that the LCAs and EPDs from different providers and systems are not comparable with each other. There are numerous national life-cycle assessment programmes each containing different Product Category Rules (PCR) on how particular environmental impacts are to be calculated and weighted. It has also become standard practise that there is only one EPD system provider in each country which, at the same time, also supplies the data basis for the national, building certification programmes (See Fig. 2).

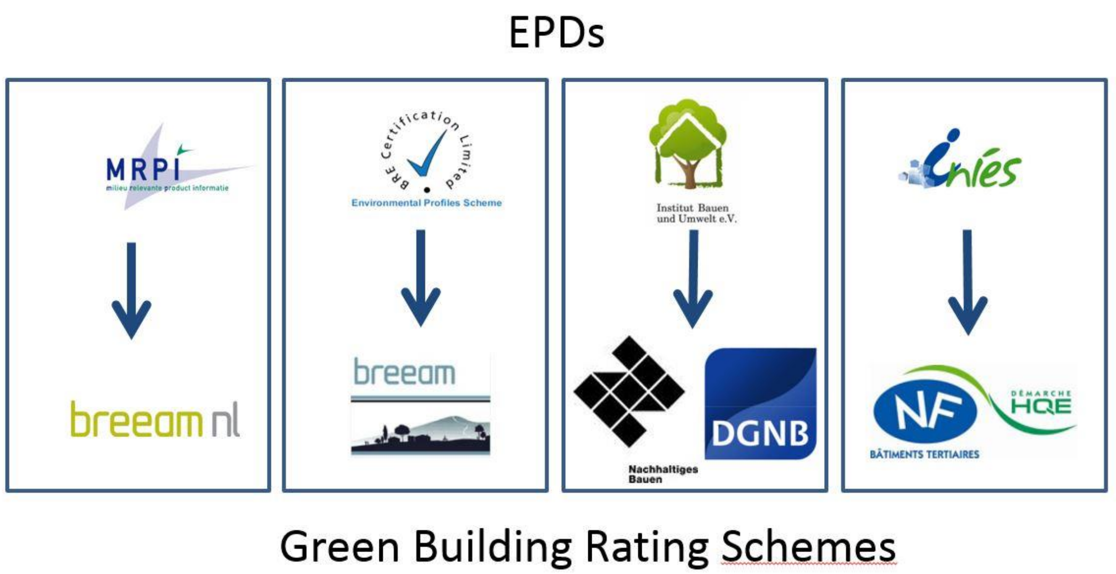


Fig. 2 Present situation of national building certification based on national EPD programs (with thanks to ECO-platform)

An international standardization of the systems, which ECO-Platform, an umbrella organisation of 13 European EPD programmes, is trying to achieve is still far off as this would necessarily entail changes in all of the national systems. The ECO-Platform members have currently not achieved more than a system of mutual recognition. The various EPD providers in Europe therefore continue to supply non-comparable data. In addition, the use of different software (the majority of European providers use the Swiss database ecoInvent; the Germans use the background-database

GaBi) leads to incompatible results. Industry also views this as an obstacle to the spread of EPDs as it is active across the European market and does not want to produce a new EPD for each country. Insecurity about the way forward is widespread. This situation means that the EPD doesn't provide the environmentally conscious planner or investor with any product selection guidance.

3.3 Labels can help with product selection

Over the past years, environmental labels (Type I Labels according to ISO 14024) have developed much further in the building industry than in other sectors. The criticism raised in the past, that they only contained the most basic of information (single-issue-based) and did not cover the most important characteristics of a product is no longer unreservedly valid. The fact is that there are still numerous labels which only contain one single well communicated message, for example the label Goodweave (formerly RugMark), which concentrates solely on working conditions within the carpet industry. This label provides no other information on the quality of the products which carry this mark.

There are however a whole range of other eco-labels which check for the exclusion of potentially harmful substances. This requires that a whole range of requirements must be met. Finally there are also more and more comprehensively orientated building product labels – these include the Blaue Engel, the EU-Ecolabel, Nordic Swan and natureplus – and it is no coincidence that these are also the internationally most important as their criteria cover a wide spectrum of sustainability requirements. These include not only harmful substances but also the origin of raw materials and social criteria in the product manufacture. Some labels, among them natureplus as the best known, also check their environmental requirements using an LCA and have even developed benchmarks for the LCA in order to underpin the comprehensive nature of their assessments.

Based upon these experiences natureplus, with the support of the German Ministry for Construction, has examined how environmental labels can reinforce the practise of sustainable procurement. The natureplus project to compare labels [3] explicitly aims at providing procurement bodies (public and private) with access to specific information about the building products to be used, which the eco-labels can provide. For instance, information is often missing about the emissions behaviour of a product. By breaking down the individual sustainability claims and the means of providing proof of them to the level of the procurement tendering texts, it is intended that investors are given a practical helping hand to encourage them to include such legally secure requirements in their procurement practise.

3.4 The natureplus grant project for comparison of labels

In order to determine those sustainability criteria which are appropriate for the tendering process, a comparison was made of labels incorporating sustainability requirements for building products in six relevant interior application areas (gloss paints/oils, wall paints, floor coverings, insulation materials, wood-based materials, plasters/screeds) from Germany and 7 neighbouring countries. In total 43 labels were included in the comparison. Of these only 21 were assessed (See Fig. 3). In the course of the examination the others proved to be unsuitable for a range of reasons. Only those labels were accepted that provided information on their criteria (Transparency), which incorporated the various interests of the construction process stakeholders (Participation), that were based on scientifically reproducible procedures (Objectivity) and that were represented in the marketplace (Relevance).

Fig. 3 Labels examined at the project “Comparison of European labels...”

From the comparison of the labels a total of 100 sustainability characteristics were identified which were incorporated into a minimum of two of the labels under comparison and thereby reflect a certain level of societal consensus regarding the relevance of these characteristics. These characteristics were allotted into the following categories:

- Restriction of substances harmful to the Environment and health
- Resource protection, environmental and climate protection
- Observance of social standards and Health and Safety

Criteria in relation to a restriction of harmful substances

The majority of the sustainability criteria identified were connected with the restriction or exclusion or undesired substances. There was a high level of consensus among the labels on the subject of the exclusion of forbidden substances, of substances of very high concern (SVHC) according to REACH, of category 1 and 2 CMR-substances and of toxic substances. On the other hand, restrictions for sensitizing agents, for environmentally harmful input materials and persistent substances (PBT) are less common but still widely specified. A common factor is that in the majority of cases all of these substances must be declared by the manufacturer if they are used as input materials and not just present in the product as impurities.

In contrast, the restrictions relating to volatile organic compounds (VOC), a substance group which above all adversely affects the indoor air quality, vary widely from label to label and depend on the approach of the label and the characteristics of the product group: This could be a restriction of the VOC content (according to the manufacturer’s declaration or a laboratory measurement), which is above all directed at the group of solvents in coating materials or it could be the exclusion of aromatic hydrocarbons, which are especially harmful to health. The most effective method is to restrict VOC emissions by employing maximum threshold limits. Compliance with these limits is monitored by means of testing chamber examinations.

Similar, but not quite as widely accepted, restrictions also apply to plasticisers (SVOC). The restrictions range from bans on particularly undesirable plasticisers (e.g. phthalates) or the restriction of the content level of plasticisers in a product (based on declarations or measurements)

to a restriction of the SVOC emissions. These emissions tests are however less widely applied than those for VOCs.
In addition, a large number of the assessed labels apply restrictions to the chemical formaldehyde. In this case they range from a restriction of the formaldehyde content level (according to declarations or measurements), the exclusion of formaldehyde releasers as input substances, to a restriction of the formaldehyde emissions. This final approach is particularly appropriate as formaldehyde is above all dangerous in its gaseous state.
A general ban on organic-halogen compounds, as postulated by some labels, is less easily implemented than a ban on ozone depleting HCFC/HFC propellants, an exclusion of problematic organohalogen fire retardants or a ban on chlorinated hydrocarbons. A general ban on biocides or at least the exclusion of especially dangerous biocides would be feasible in the majority of product groups but an exception must be made in some cases for pot-preservers. In this case however, harmful halogenated preservatives, for instance, can be excluded.
Further exclusions or threshold limits that are in wide use by European labels apply to problematic metals and metal compounds, to chromate (chrome VI) and to cobalt compounds which can be found in certain products. Less widely used are odour tests or radioactivity and radiation measurements. Alongside these are a large number of diverse individual substances, which – depending upon the particular product group – are less frequently the focus of criticism in terms of the criteria of the labels assessed.

Criteria in relation to resource and climate protection

In comparison to the preceding categories the number of sustainability criteria in the area of resource and climate protection is relatively limited: The primary criterion is a minimum percentage of renewable raw materials as well as the use of secondary raw materials (e.g. old glass or industrial gypsum) to minimize the consumption of resources.
In particular, the origin of timber as a renewable raw material is the subject of heavy focus. The minimum requirement is therefore: no exploitative felling in timber harvesting supplemented by the use of regional timber resources and culminating in the promotion of sustainable forestry practises, of which there is already a tradition in central Europe.
Another widely addressed issue is the avoidance of waste. Requirements on the nature of packaging (reusable packaging, resealable packaging, halogen-free packaging) are particularly well established in Germany. Requirements for unproblematic disposal and the avoidance of dangerous waste materials are focussed on a general recycling of the products but, based on the response from the labels, it hardly seems a feasible goal at this time. A ban on PVC as an input material is however another story as this is already applied by some labels.
More general issues such as demands for energy efficient production or the reduction of greenhouse gases in the production process usually fail due to lack of appropriate tools/procedures for their measurement. Theoretically this could be achieved using an LCA or an EPD – if these could be measured against certain benchmarks.
Requirements for the usage efficiency (suitability for purpose and, above all, durability) are applied occasionally. They can however be counterproductive if the higher usage efficiency is linked to an increased environmental burden.

Criteria in relation to social compliance

The social criteria that are currently present in the labels are very limited. They restrict themselves in general terms to compliance with the core working standards of the International Labour Organisation (ILO), in particular to the issue of child labour, and to references to essential protective measures (protection against dust, fumes etc.).

From the 100 sustainability characteristics recognized as relevant to building products, 62 were appraised as appropriate for the tendering process. These were integrated into the tendering process aids.

Table 1: Project results

Sustainability characteristic	Criteria found	Suitable criteria
Restriction of substances harmful to the Environment and health	55	33
Resource and climate protection	38	24
Social standards and Health and Safety	7	5

The most important criterion for inclusion in the tendering aid was the verifiability of the corresponding characteristics. The environmental labels provide the relevant information but the public procurement law does not permit that the fulfilment of a criterion is provided solely on the basis of an environmental label. There must always be alternative means of verification and these must be available to an adequate degree. Above all they must be presented in a manner which is comprehensible and appropriate for stakeholders who are not particularly well versed in this complex area (bodies inviting tenders, those submitting tenders, the contracted building firms).
It must be also be taken into account that this approach has a European dimension whereby national rules are not regarded as a sufficient proof of compliance. In addition to a manufacturer's declaration, which can naturally only make reference to elements which are more or less obvious, documentary evidence which is valid Europe-wide, such as declarations according to REACH or certain regulations e.g. employment protection, constitute the most important proofs of compliance. In only a few cases are widely used tests applied – for example in relation to the emissions of VOC (volatile organic compounds) or in the case of an EPD (Environmental Product Declaration) – which are already legally established in numerous European countries.
In some cases different environmental labels used various compliance definitions for the 62 sustainability characteristics recognized as relevant to building products, for example in the threshold limits for harmful substances. Within the framework of the research project, those definitions which were stipulated as sufficient by the majority of the labels under consideration were taken as the basis. In many cases these correspond with legal or declaration limits.

Sustainable Tendering/Procurement Guidelines

The characteristics of sustainability chosen as suitable were formulated for all six building product groups and presented as a standard text of tendering process documentation for public and private procurement bodies. These standard texts can be used in every phase of the tendering process – from the specification of requirements, the definition of suitability and contract award criteria, to the stipulation of the methods of execution. The texts are to be used as a modular system and will be free and openly available at the natureplus homepage www.natureplus.org. So the procurer can chose which characteristic is really relevant for his object.
The structure of the text modules is standardised: First the criterion is described precisely, then all relevant and available proofs are listed to verify the fulfilment of the specified sustainability characteristics (e.g. the material safety data sheet following REACH restrictions) and at least all the labels which show the same characteristics are listed. So the procurer can rely on every product carrying one of the listed labels in this respect. The standard texts in such fulfil the stipulations of the public procurement directive.

4. Discussion

If the results of the two investigations conducted by natureplus are compared, it is apparent that the reason EPDs perform so poorly relative to labels is that they are comparatively new tools for the measurement of environmental impacts. If it were possible to present the LCA results in a form that allows a clear and easy comparison of all factors, to include benchmarks and also to supplement the EPD with certain compulsory laboratory tests then, due to the fact that they cover the complete product life cycle, they would even be superior to the labels which employ a holistic approach. However it is likely that this will take at least a decade. In contrast, labels offer a far greater level of consumer guidance on the best choice of environmentally sustainable building products, even if one has to admit that the criteria identified often only deliver a sketchy description of the sustainability of building products. The fact is that we have a far clearer understanding of what we don’t want (in terms of harmful substances) rather than what defines a good, sustainable building product.

5. Conclusion

The EU states are obligated to adopt the stipulations of the EU Public Contracts Directive 2014/24/EU in to national law by 18th April 2016. Through the law on the modernisation of the award of procurement contracts (Vergaberechtsmodernisierungsgesetz), the German Federal Government is in the process of fulfilling the requirements of the EU for the inclusion of sustainability criteria in to the tendering process. In order to meet these requirements the procurement bodies are reliant upon the provision of pre-prepared information on the sustainability characteristics of building products that is relevant to the procurement process as well as the corresponding proof of compliance documentation which must be submitted. As the discussion has shown, EPDs cannot - in contrast to the position postulated by the government – deliver this information. This research project, by analysing 21 environmental labels from 8 European countries, has identified 62 sustainability criteria which are suitable for the tendering process and has prepared 6 tendering process aids for building product groups relevant to interior applications.

6. References

[1] DIRECTIVE 2014/24/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 February 2014 on public procurement and repealing Directive 2004/18/EC.

[2] REGULATION (EU) No 305/2011 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC.

[3] Comparison of European labels incorporating sustainability requirements for building materials, (The introduction of sustainability requirements for building products in the tendering process. Simplification of the evidence procedure through the use of labels) by Thomas Schmitz, natureplus e.V. Neckargemünd. Subsidized with funding from the Research Initiative “Zukunft BAU” of the German Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) Project II3-F20-13-1-073 from September 2015.

Learning by Doing

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Summary

The seminar “Materialization 2 – Construction Site Visits“ which was held in the 2014 summer semester (SS 2014) at the TU Graz, is about teaching site-related aspects of sustainable building. By means of a holistic approach as well as a variety of methods and competences, which architecture students will need later in their profession, can be awakened and promoted.

Keywords: seminar, teaching methods, building sites, skills development

1. Starting Situation in architectural Teaching

The term “sustainable teaching” has at least two meanings in the construction sector. On the one hand, it means the teaching of sustainable building, certifications, backgrounds and the like. On the other, it can be understood as the teaching that is sustainable itself. “The durability of our actions shall be the driving force for new activity!” [1] - this does not only apply to construction, but also to teaching. It takes place in the following sketched framework:

First of all, the profession of an architect or construction engineer has changed considerably in recent years and decades in several respects. Keywords are IT, changed laws, new materials and possibilities. It is assumed that the requirements placed on professionals in the construction sector will continue to change in the future [2]. If universities want to align their training on the requirements of the later professional practice, they will have to adapt their curricula accordingly. As a consequence, especially in master’s degree programmes less knowledge but far more competences have to be taught [2] which will help to manage engineering tasks in the future that are not even foreseeable at that moment. Therefore, one needs to qualify the students for their future practice (qualification according to [3]).

Secondly, for years [4] [5] there has been and still is [6] the call for the training of architects to be more closely aligned to the later professional practice, especially regarding technical-constructive, economic and organisational tasks. But in this country, universities and universities of applied sciences (“Fachhochschulen”) frequently offer studies that are increasingly draft oriented. Presumably, this occurs for the simple reason that schools of architecture want to adapt to internationally prestigious schools (as, for example, those described in [7] in English-speaking countries). This is understandable in light of increasing internationalisation, but it ignores a distinctive feature: designing is only a small part of architectural activities in German-speaking countries.

Thirdly, the draft itself is therefore only a small part of the remuneration according to the HOAI (fee structure for architects and engineers in Germany [8]). According to these remuneration arrangements, about ten per cent of the fees correspond to the preparations of the tender [8], which is the generation of service specifications, a substantial part of which is the authoring of texts. A larger part of the architect´s fee goes back to service phase 8 (LPh 8) for supervision tasks, which is 32 per cent. Thus, German architects earn (at least so far [9]) a not insignificant part of their incomes from non-drawing activities. In Austria, the fee structure is not compulsory any more [10] and furthermore, supervision tasks (ÖBA = local site supervision) have not been regularised in the HOA (fee structure for architects), but it still remains a noticeable income option for architects.

The fourth aspect of the initial situation of this paper is the scientific demand which is more and more often placed on university teaching as well as on the instructors in the building sector. Especially the connection to supervisory tasks and the familiarity with construction sites are therefore rarely encountered. This makes it difficult to adequately and profoundly transmit knowledge and practical elements as part of a holistic approach to architecture.

The author of this article has been teaching at TU Graz after more than ten years of construction site experience. The seminar presented here “Materialization 2 – Construction Site Visits” with course number 149.806 had the goal of bringing construction practice and the possibility of working there closer to the students. At the same time, they were supposed to work for and to acquire competences which they will need in the long run and are therefore sustainable.

2. The Seminar “Materialization 2 – Construction Site Visits”

2.1 Framework of the course

In the course of a seminar for master students, which is credited with 2 SWS (3 ECTS), only limited competences and sustainable ways of thinking can be taught. Nevertheless, this opportunity was used to develop sustainable competences among a group of students by means of a holistic approach.

Process components of the course (according to [11]), that is intentions, contents, methods and forms of organisation were optimally matched. The intentions are each subsequently mentioned as an explanation within the various components. The methods are a combination of well-known elements (project report, action-oriented teaching, lectures, correction dates) as well as unusual teaching methods. Next to transferring knowledge and the acquisition of skills, student autonomy was explicitly expected and encouraged.

2.2 Organisation

Characteristics for good teaching are (according to [11]) amongst others a clear structure, technical correctness, enunciated expectations, a learner-friendly working atmosphere, variety of methods, regular feedback as well as initiation of maturity. These characteristics were implemented as follows.

2.2.1 Time schedule

Very often, site visits are block courses. It is also intended that way at TU Graz. But in order to achieve teaching targets, this seminar was dispersed across the summer semester. In terms of course meetings and deadlines, the following considerations were relevant:

- introductory session and first common excursion at the very beginning of the semester
- submission deadline and final presentation one month before the end of the lecture period

These two premises resulted in the time schedule presented below. The initially planned, blocked period of time in calendar week 19 is dashed. The early start allowed students to organise the expected achievements in their own authority. The exceptionally early end of this seminar gave students enough free space to work for other courses, which is normally necessary towards the end of a lecture period. That way, the quality of the results of the described seminar was meant to increase at the same time.

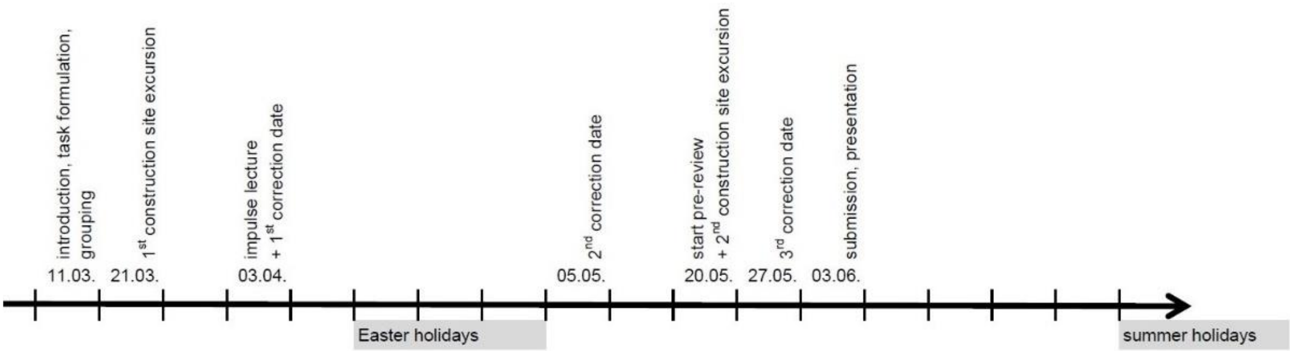

Fig. 1 Time schedule of seminar 149.806 in summer semester 2014

2.2.2 Students

Usually, a manageable number of students attend seminars, 21 master students of architecture took part in the course mentioned here. They had 10 different nationalities, six students were incoming students. We formed eight small groups and none of them were allowed to include more than one incoming student.

This had two aims. First, the Time schedule of seminar 149.806 in summer semester 2014 incoming students were to be integrated into the groups, so that these students, none of whom spoke German, at least got a chance to complete the issued tasks, for the simple reason that hardly any English is spoken on Austrian sites. Second, regular students who had perhaps already completed several study projects together in a fixed group were forced to integrate new group members, communicate with them in a target-oriented way and work in a team (aspired competences according to [2]). Later, in professional life too, an architect cannot necessarily choose the people he wants to work with. And perhaps he will then discover that for example structural engineers or construction physicists speak “a different language”.

It was also important for the task formulation that students had already completed a bachelor’s programme and thus had had the appropriate technical training as well as certain maturity and communication skills.

2.2.3 Templates

Students of architecture can put a lot of effort into their studies' layout, which is generally a good designing exercise. In this seminar, however, students were supposed to concentrate on content. Therefore, the use of digital templates was obligatory for the written requirements as well as for the presentation. Furthermore, these templates made it immensely easier to issue the respective contributions in the institution brochure [12].

2.3 Methods

Site visits are a common way of transferring knowledge in the field of architecture and civil engineering. They are unquestionably important for the visualisation but are often associated with rather little student activity. Maybe students have to prepare short presentations or have to draw up reports afterwards. Mostly, however, many students more or less walk through the site as a group. While some of them get the excursion leader's explanations, others are often cut off from them simply because of the noise level at the site.

In the seminar described here, further elements were intended to stipulate students' activity besides common academic teaching methods, leading to a more sustainable transfer of knowledge (see [3], [11] or [13]).

2.3.1 Common methods

Different methods from the common repertoire were used in the seminar: one was the lecture as a possibility to communicate compressed knowledge. This was especially important because there is relatively little literature on the requested topics, which would "only" give the necessary overview to students. There were also shared site visits. The one at the beginning of the summer semester was particularly important, in order to illustrate several aspects of the task formulation in situ through this example.

Work based on actual projects is standard in architecture as well as work in small groups. The latter does not only promote the ability to coordinate with others but also enables handling extensive and challenging projects due to a distribution of tasks. Further quality criteria of group work, such as self-organisation and the coordination with other groups were added [3].

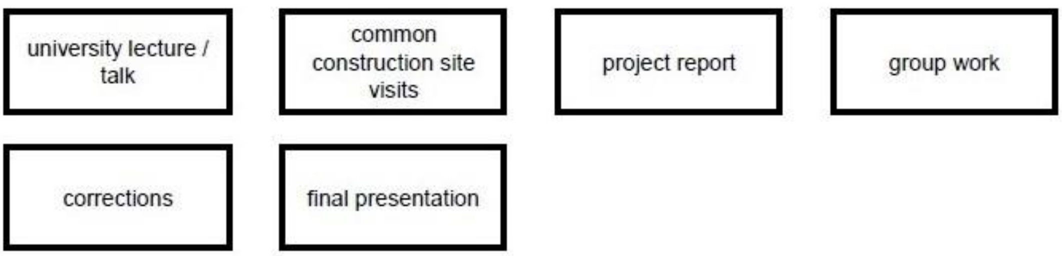

Fig. 2 Common teaching methods in seminar 149.806 (SS 2014)

It is usual in architecture that students can use the opportunity of having the papers they are working on be corrected by a teacher occasionally. This way, questions and uncertainties can be clarified, wrong tracks can be avoided or positive developments be confirmed. In order to promote the students' autonomy, the described seminar also offered students to sign up for corrections via a doodle-email response, but there was no obligation to attend. A presentation in the plenary at the end of the course was, however, compulsory, while each small group only presented certain aspects of “their” site. Generally, this included something that distinguished theirs from other’s, i.e. was a speciality.

2.3.2 Exceptional methods

Distributing incoming students over all groups (see 2.2.2) is one of the not very common methods, but it can also be found elsewhere. Obligatory, individual site visits for students, however, are probably more unlikely. The tasks were purposely assigned in a way that such visits became necessary. The questions could not be answered through literature or through internet research, but they challenged the students. They were each issued a short profile of various building constructions in Graz, which they would have to investigate as well as contact data of the corresponding architect’s office. They had to arrange on-site inspections with these offices themselves, so they did not only have to coordinate within their group but also with external persons. As only with their help were the students able to answer the site-related questions.

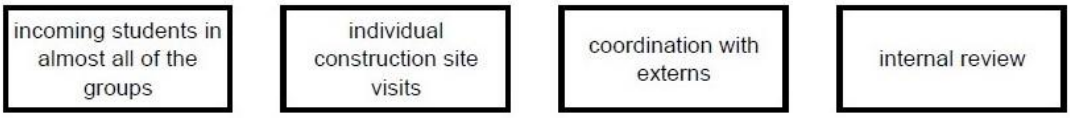

Fig. 3 Exceptional methods in seminar 149.806 (SS 2014)

The results of these on-site inspections had to be formulated in texts and in hand-drawn sketches. This ability still continues to be necessary in the CAD age especially for technical architects. It can be an effective tool for students because it forces the drafter to recognise the essential point of a situation and also to make a written note of it. Therefore, as far as conciseness goes, it is far ahead of many an exact drawing, most of all, the photo which is omnipresent nowadays.

The most exceptional teaching method of this seminar must have been the internal review- process. Two weeks before the end of the seminar, each group had to hand out its report to another group (with a similar project, e.g. a group also working on school constructions or housing constructions) and to the teacher of the seminar. This report had to be “corrected” then: Is the presentation understandable for third persons? Are the questions answered completely and logically? Do texts and drawings match? Is the language correct and appropriate?

One week later, the corrected reports were returned, so that the comments could be implemented by the respective authors early enough before the end of the course. The teacher also received the “corrections” for information.

First of all, this method was designed to increase the quality of the reports. Then it was about bringing a further project closer to each group in detail as well as demonstrating potential weaknesses of one’s own report. Third, this process was designed to be practice for working as an architect later, which implies a division of labour especially in the case of larger projects. Within such a division of labour, it is typical that, for example, tender specifications are corrected. This is carried out by architects (and civil engineers), who work in project management, but also by planning- and supervising colleagues.

2.4 Contents

“You have nice events – you gain experience!” [11, p. 335]. True to this motto, the seminar participants did not only have nice experiences together in the form of excursions but they also had the opportunity to each gain their own experience within the small groups. Nevertheless, the content input of the report was of particular importance.

2.4.1 Report

“You only see what you know”, this principle is especially true for sites, where non-professionals (which most of the students are) often get the impression of an obscure chaos. Therefore, the teacher divided this “chaos” into theoretical pieces that were manageable for students, on the one hand. And on the other, diverse contexts were presented in the form of classroom teaching, especially contexts between the “great” ideas, e.g. the sustainability of a project, and many small steps that become necessary for the realisation of a building.

2.4.2 Joint site visits

On two days, all participants visited larger sites in Graz together. The limitation of Graz was meant to save time and money and to additionally give students a chance to possibly visit the sites more often and thus observe the progress. As two projects could only be realised after a lengthy public discussion, they additionally provided the opportunity to talk about precisely that issue in the seminar.

The first and the second construction section of the medical university (architect: Riegler-Riewe) are in the immediate neighbourhood to the state hospital. Shortly before being commissioned, it became clear that a lot was left to be done in the first construction section, concerning buildings that would require a lot of technical work after the construction’s completion, e.g. the adjustment of the ventilation system. During the site visit, the foundation work was being carried out in the second construction section; the complex slope stabilisation by means of trench shoring was impressive.

The “Pfauengarten” – project (architect: Pichler & Trampmann) was very controversial in town, as it is located in direct proximity to the UNESCO world heritage old town. More or less as a side effect, a social aspect of constructions was thus touched upon: “in architecture, society becomes visible in all its complexity” [14]. With regard to the actual target of the seminar, particularly the special measures for the so-called re-shoring were impressive. Some floors are statically suspended from the roof level. This is why they had to be supported elaborately, partly with temporary, concrete pillars on the same fundaments, until the ferro-concrete roof frame had reached its final solidity. It became clear that not every construction that is technically feasible and that was possibly ultimately built with reduced materials automatically means that resources have been used carefully.

The renovation of the “Hafner-Riegel” – project (architects: Werkgruppe Graz / Architektur Consult) showed the student some of the challenges that arise, when stock is reworked for future-oriented use. In the interest of sustainability, a lot of building material and thus “grey energy” (embodied energy) can be reused but it often demands more creative inventiveness and expert knowledge than a new construction.

2.4.3 Individually visited sites

As mentioned in the beginning, students were supposed to get in contact with sites through this seminar and on top of this, deal with site relevant issues. Therefore, the contents were not only designed for the “product”, the complete building, but for the necessary steps, resources and methods. The students had to find out about temporary site facilities as well as about documentation and quality management measures in addition to general information.

As shown in the short profile, these were, on the one hand, infrastructural elements (for example building-site offices) and safety measures like scaffolding and fences and site logistics. The effort involved is often substantial, which became clear to many students during this seminar – partly for the first time. In general, it is increasingly recognised to look at the entire life cycle of a building. The fact that part of this life cycle can also include many, partly very elaborate and only temporary measures, energy-intensive temporary provision or innumerable containers with construction site refuse during the construction, was clearly demonstrated in this seminar. Economy and ecology as aspects of sustainable building can – or cannot – find their way into construction site facilities.

As documentation of construction sites is becoming more and more important not only legally but also as an element of process quality, it is also becoming part of the concept of sustainability (see [15]). Documentation and possibly setting up an office for construction quality management can increase the technical quality and thus the durability of the built object and therefore lead to more sustainable construction.

Fig. 4 Group photo of the excursion on 20th June, 2014

3. Results

3.1 Results from the teacher´s point of view

All students passed this seminar; all small groups grew through the tasks they had to complete and they succeeded in their (examination) work. From the teacher´s point of view, some were nearly unable to cope with the group-coordination. The ability to produce and submit freehand sketches was hardly present or the courage for such an “imperfect” presentation was lacking. In part, the courage to correct the work of colleagues was also not strong (enough).

In a seminar with 3 ECTS, such a large substantive field can inevitably only be touched upon, but not comprehensively worked through. So far, it cannot be said whether the spark of enthusiasm for construction sites was lit. But that, on site, there is a lot more to implementing large and small projects than simply a crane and a digger, was definitely made clear.

3.2 Evaluation of the seminary

Ten students participated in the online-evaluation [16] that is almost 50 per cent of the seminar’s participants. They marked the seminar as “very good” to “good” regarding content, execution and requirements. The time schedule met everyone’s approval and the students valued the work in small groups and the choice and diversity of the projects nearly as positively as well.

1.1.4) Was gefällt Ihnen an dieser LV besonders gut?

- Die praxisnahen Besuche auf der Baustelle und die Möglichkeit sich mit den jeweiligen Personen auszutauschen.
- Die Auswahl der Baustellen die gemeinsam besucht wurden fand ich sehr gut, da sie auch historisch gesehen spannend waren.
- Das besichtigen der Baustellen, so dass man diese auch in der Praxis sieht und nicht nur in der Theorie, wie in anderen Lehrveranstaltungen.
- Der nahe Kontakt zu den Projekten. Incl Hintergrundwissen zu Problemen, die sonst nicht ausgesprochen werden.
- Contact with several construction sites.
- Pretty happy with this LV structure.
- I think all the visits were conducted in a very professional way. The objectives were clear and scheduled. I learned a lot. The improvement is always at the prejudice of existing constructions and I liked all the sites we visited. Good seminar!

Fig. 5 Extracts from the online-evaluation [16]

4. Discussion

4.1 Cost-benefit-analysis

Even though sufficient appropriate construction sites for such a seminar can be found in almost any university town, finding them is not everything. After all, the projects that the students had to contact autonomously needed to be in a construction state that was task-appropriate. Experience is required in order to be able to assess this in the run-up. Beforehand, the respective architects have to be asked and not every office takes time for students.

Although, thankfully, there were no construction site accidents, insurance issues had to be taken care of in the run-up as well. All students received a helmet from the institute and they were obliged to commit themselves in written form to an “on-site” code of conduct for safety reasons.

Different to, for example, lecture courses or basic seminars, the teaching notes from this kind of seminar can hardly be reused. In case of recurrence, the effort of finding suitable construction sites and coordinating with external partners (which took a total of about one to two weeks for this seminar) would have to be repeated. Seen from this angle, the teaching concept presented here is uneconomic. But in light of activating students and of the high practical relevance in the field of teaching, it is worth it.

4.2 Critical review

In adult education, there are, among other things, the “pedagogical guidelines” of viability and sustainability (Horst Siebert in [11]). The first one refers to pragmatic, viable, approved orientation in the here and now. Such an orientation was definitely given through this seminar. While, in this case, this was also due to the teacher, surely all teachers could do so, who are capable of bridging the gap between university and (construction site) practice.

The second pedagogic guideline, sustainability, implies “…a check of the future ability of our thoughts and actions.” [11, p. 298]. Actually, every seminar should pass such an examination. The seminar described here, should surely pass such an examination, not only because of its holistic approach, its variety of methods and its organisation that was aligned to the contents and aims.

5. Conclusion

The contents of the described seminar originate from the job outline of an architect in German-speaking countries. But even there, where construction management is not part of the later professional activities of an architect, construction sites and all the measures to put up a building are (hopefully) immanent study contents. In the course of holistic teaching, which is increasingly more important and common due to life-cycle analyses in sustainable building, the reference to construction sites may not be weakened in the curriculum, on the contrary.

Activating students, involving externals as well as the variety of teaching methods are further aspects of this seminar which can also be used in countries where architects are used to having a more specific focus on drafting. But in those instances, a far more intensive support of the students would be necessary. Within the scope of holistic, sustainable teaching, single elements may possibly be supplemented by e-learning, but on no account can they be replaced.

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Learning from Ethiopia – A discussion on sustainable building

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Summary

Ethiopia is developing at a mind-blowing pace with a booming construction industry as one of the main driving forces. We, as German architects who teach and research in Ethiopia as part of an Ethio-German university cooperation, were interested in finding out whether sustainable building was realized in Ethiopia or not and whether the concept was critically reflected. In order to advance this complex issue, we chose an inductivist approach: With the help of two interviews and two text resources we created a multi-layered story on sustainable building in Ethiopia told by Ethiopians. From this, we learned that sustainable building is lacking appropriateness for the Ethiopian context expressing itself in a lack of professional discourse and implementation. A chance to improve this situation might lie in the appropriation of the concept by Ethiopians challenging a concept that was created by Westerners for the West. Secondly, we suggest the concept of urban and architectural resilience as an additional tool for achieving sustainability goals. Its core values are change and creativity – both qualities inherent to Ethiopia's rapidly growing urban centers. This paper is intended to contribute to a much-needed Ethiopian and global discourse on the appropriateness of sustainable building as a fundamentally Western concept.

Keywords: Sustainability, Ethiopia, Material, Appropriateness, Resilience

1. Introduction

"Appropriateness is a moving target" was the name of an article written by Dirk Hebel in 2010, then director of the EiABC, the Ethiopian Institute of Architecture, Building Construction, and City Development [1]. What he was getting at was the ambiguity of deciding what *good* architecture in Ethiopia meant, a land-locked country at the Horn of Africa, with little but an ever-growing population to support its booming construction sector. Consequently, we ask whether "sustainable building" is appropriate in this context. Can we, should we apply the same measurements and tools used in Europe over the last some 30 years? This paper bases on research carried out in collaboration with EiABC in 2015 with Addis Ababa as a showcase. A microscopic analysis through interviews and a macroscopic analysis through reviewing Ethiopian scientific writing reveal a snapshot of the practical application of and the discourse on "sustainable building" in the Ethiopian housing construction sector. Carefully listening to this discourse, we reflect the appropriateness of "our" (i.e.

Western) understanding of sustainability. The way, in which this research is published as well as its focus on the practical application of sustainable building in Ethiopia is unprecedented. We therefore hope to contribute to a much-needed professional discourse in Ethiopia on sustainable building and a just as much much-needed global discourse on creating appropriate standards on how to implement sustainability goals in developing countries.

1.1 Addis Ababa

Some background first: At the time of this research, we have been teaching, researching, and experimenting with architecture in Ethiopia and Germany as part of an Ethio-German university collaboration since 2008 and 2009 respectively. We are drawn to this country's spectacular development pace, to its unique history, to its diversity, and to the challenges connected to all of that.

The year 2015 is a good moment to reflect on the issue of sustainable building in Ethiopia. As many other African countries Ethiopia is torn between *"globalized hypermodernity and living traces of a vernacular"* [2]. Especially the capital Addis Ababa is suffering from a "tabula raza" mentality: While the newly released GTP II[1] is being enforced as we speak, the historically evolved "*non-centralized, non-segregated, non-functionalist*" indigenous urban tissue [4] is being replaced with modernist housing, commercial towers, ring roads, and highline tramways. Traditional building practices are forbidden, while building with concrete, glass, and steel is encouraged in a country with nearly no natural resources to support this construction practice [5]. It is necessary to emphasize that the historically grown neighborhoods of Addis Ababa have advantages to new, high-rise housing developments, amongst which are spatial and social diversity. On the other hand, these neighborhoods unquestionably suffer from overcrowding, bad access to sanitation, and dilapidated housing stocks [6]. In 2004, the federal government launched the *Integrated Housing Developing Program* in order to replace Addis Ababa's rundown urban housing stock, to reduce the housing backlog of then over 200,000 units [7][2] and to develop a formal construction sector. Therefore, as the old city vanishes and a new one emerges in leapfrogging pace, it will be valuable to look at the current building practice and its underlying concepts.

1.2 Sustainable building

According to Marianne de Laet and Annemarie Mol, the appropriateness and working of a device in the context of a developing country should not be measured through a generalized, international standard. A great example is the "working" of the Zimbabwe Bush Pump as a hygienic intervention which is measured by the number of E.coli in 100 ml of pumped water. This standard is inappropriate, the authors argue, as the group of people using it might be used to that type of E.coli. Appropriateness much rather depends on what de Laet and Moll call "*the practical comparison of alternatives"* [9]. Following their argumentation, we must ask whether "sustainable building" is an appropriate standard for Ethiopia?
Before we can address this question, we need to briefly establish a definition for "sustainable building". For this purpose, we adapted the fairly broad definition of the 1991 established *Strategy for Sustainability* for the purpose of this paper: Sustainable building is to "improv[e] the quality of human life while [designing and building] within the carrying capacity of supporting eco-systems" [10]. Acknowledging that this definition is probably valid most of the time, we will closely observe

[1] Ethiopia's second 5-year "Growth and Transformation Plan" with which the the Federal Government tries to achieve its "long-term economic goal of transforming Ethiopia into a middle-income country by 2023" [3].

[2] This number is debated: e.g. Azeb Kelemework estimated this backlog to be 400.000 units in 2006 [8].

what De Laet and Moll called the “practical comparison of alternatives” [11] in order evaluate whether it is *appropriate* in contemporary Ethiopia.

At this point of the narrative, several questions regarding sustainable building in Ethiopia are emerging: *How is contemporary housing constructed? Do sustainability aspects have a role in housing design and the choice of construction methods? Is our Western model of “sustainability” appropriate in Ethiopia?*

But how do we answer these questions without being patronizing, without looking through the glasses of Western education and knowledge production? The next section will look hat how we might be able to advance this issue.

2. Methodology

But before we can start to think about the “how”, we will briefly need to look at why Westerners seem to only hear and speak about Africa in a certain way. Only after we understand that, we can move on to deciding how to conduct our research on sustainable building in Ethiopia. The global narrative on Africa as a continent of catastrophe is still determined by Europe and North America as Nigerian novelist C. N. Adichie poignantly characterizes in her speech *The Danger of a Single Story*: “This single story of Africa ultimately comes, I think, from Western literature" [12]. A quick perusal of past and recent scientific essays, books, and papers on Africa’s architecture confirms this imbalance while sustaining an incomplete (i.e. single-sided) image. This image creates not only stereotypes but also manifests the dominance of one epistemology, the Western one. Looking for illustrations of this in African architecture, one must only look at the modernist ideals of urban centrality, the car-appropriate city, or machine-architecture as tokens of an *orderly city* and a *modern way of life*. How, then, can we as Westerners research in and publish on Ethiopia without telling a single-sided story? How can we avoid basing our research approach, our claims, and our conclusions on our personal backgrounds[3]? In her book "Strong Objectivity and Socially Situated Knowledge”, Sandra Harding suggests turning informants into eye-level research participants: Only if research begins “in the perspective from the lives of people on the ‘other side’”[13] *strong objectivity* is created. Therefore, the key to achieving our research goals while creating a strongly objective text was to develop a research approach that would allow us to “find out” while making it explicit that the knowledge collected was not ours, but Ethiopian. According to Kwa’s contribution to the book “Complexities”, one possible approach to this issue is “baroque complexity” which artfully adds different standpoints in a bottom-up-approach [14]. This research approach does not only address strong objectivity but it also the task of assessing our incredibly multi-facetted research subject: sustainable building in Ethiopia without ending up with a scientific text in chaos.

In order to create *baroque complexity,* i.e. in order to layer different standpoints in a scientific text, we had to first select number of case studies (text and interviews). At the same time, we could not but had to understand each of those case studies as non-representative. Instead, case studies fulfil other purposes: “For instance, they may sensitize the reader to events and situations elsewhere [and they] may act as an irritant, destabilizing expectations“ [15]. Therefore, our cases – two interviews and two text excerpts which are presented in the next chapter – are not intended to transport some holistic but their own system of knowledge. By overlapping these knowledge systems, we are able to learn about the complex issue of sustainable building in the housing practice of Addis Ababa without appropriating local knowledge as our own.

[3] According to Sandra Harding (1991), knowledge is always produced from a distinctive social, cultural, and economic background. The resulting “situated knowledge” is the product of distinctive disciplinary thinking, socialization, societal standing, historical background, cultural norms, ideals, etc.

3. Two conversations and two texts

3.1 The self-builder

The following interview is one of a total of ten interviews which were conducted between September 21 and 29, 2015 by four Ethiopian research assistants. We chose to include this particular interview because the informant showed a high awareness of his material choices and because his construction project was the most recent therefore showing great actuality. Ermiyas[4] meets Tesfaye Akalu[5] at the fringes of Addis Ababa. The interview is conducted in Amharic and later transcribed by the research assistant. The research team edited the transcription where spelling or orthography made it necessary and shortened it by two thirds for this paper.

E: Can you tell me something about your house and the people that will live here?
TA: As you can see the house is not finished yet. The construction started about six months ago. When we finish constructing, my mother, my grandmother, my two brothers, and me will move in […]. After we leased the land, we built the foundation and a septic tank. Plus, as you can see we built the stairs, too. After a while, we will start constructing the walls. [For now], we have stopped construction, which is due to the price escalation of construction materials […]. The shortage on top of the price escalation of materials makes it very hard to finish work on time […]. As soon as the price of steel drops, we will definitely re-start construction. So far, we have built two slabs and they cost us around 200,000 ETB [around 10'000 Euro] […].

E: What kind of materials did you chose for the house and where did you buy your materials from?
TA: It is not a matter of choice to be honest. I buy the material according to availability and financial status […]. The floor is concrete. That is for strength purposes. The walls, which will be started soon, are going to be made of hollow concrete blocks. And for the roof, we are going to be using corrugated iron sheets. This is because of price and efficiency with regards to our financial resources […]. For this project, I used cement from the Derba cement factory. It is locally produced. In addition, I can say happily that I will get my HCB supply from local cooperatives that are run by young entrepreneurs I know in my neighborhood. I am happy that I am helping their business.

E: You mentioned recycling earlier. What did you mean by that?
TA: The eucalyptus scaffolding is going to be used after we finish the house construction to conduct other smaller constructions later […]. We also re-use corrugated iron sheets. The concrete waste is going to be used to pave the compound and landscape the front yard. That way, I believe we can minimize wastage and save our resources […].

E: What is your perspective on sustainable building materials like bamboo and rammed earth?
TA: I didn't have the need to use those materials before and I do not think I will have that in the future. Why? I think that is because of personal taste. I do not think I am a bamboo type of guy. Additionally, strength is a big question for me. I don't think I could build a multi-story housing unit with those materials. […] As a person who grew up in a mud house, I have seen many unpleasant things. And I want to change that. I want to live in a house made if modern and contemporary materials […]. What I understand as sustainable is a structure that can stay long without any maintenance or alterations. But I do not think houses made of bamboo or mud can be as sustainable as the ones that are built with more rigid materials such as steel and concrete.

[4] Master student at EiABC and one of our research assistants.

[5] The name was changed as the informant wished to stay anonymous.

3.2 The Ethiopian Construction Directory

Between September 17 and 21, the 12th International Construction Exhibition “Ethio-Con 2015” took place at the Addis Ababa Exhibition Center. Visiting the fare, we intended to get an impression on whether material producers and builders were addressing “sustainable building” in Ethiopia. While the information presented there did not explicitly deal with the issue, we were able to acquire the Ethiopian Construction Directory Volume 2 as a source of information regarding the Ethiopian view on “Green Construction”. As we were about to leave the booth, the editor of the directory heads up to greet us. When asked about sustainable building, he explained that so far the Ethiopian construction industry had been all about moneymaking and not about sustainability. Afterwards, we closely examined and excerpted the key sentences of the 6 page “Green Construction” section (all of which has 230 pages) to find out what the “Ethiopian Construction Directory Volume 2” would reveal about “sustainable building” in Ethiopia. The first part of the chapter states that “sustainable or ‘green building’ design and construction […] involves finding the delicate balance between homebuilding and the sustainable environment” [16]. The authors then point out: “Rigorous quantitative Whole Building Energy Analysis and Life Cycle Assessment methodology […] and enforcement of these enhanced standards will significantly reduce […] energy consumption and avoid substantive greenhouse gas emissions” [17]. Finally, the authors close with examples of “sustainable” building materials including a whole page on vegetation blankets for green roofs and half a page on the use of spray polyurethane foam (SPF) insulation for reducing “heating and cooling cost” [18].
The evidence from the trip to the fare and the findings from the directory suggest that the Ethiopian building industry has adopted a simplified approach to sustainability focused on resource use. Important issues such as architectural quality, socio-cultural aspects, or adaptability are left out.

3.3 The architect

Rahel Shawl is owner and lead architect of RAAS architects, one of the most successful and famous architectural practices in Ethiopia. The interview was conducted by Nicole Baron in English at the office of RAAS architects in Addis Ababa. For the purpose of this paper, the spoken word was slightly corrected and shortened by two thirds while trying to preserve the original tone.

NB: What is sustainable building for you and how do you implement it in your projects?
RS: I’m reading a lot about this new idea of sustainability and how it is practiced in other parts of the world. Is it just wishful thinking? Or is this question only for us? [Laughs] When we do smaller projects we try to use locally available materials and craftsmen […]. We try to preserve trees, we try to use solar panels, we use water treatment. [Air-conditioning and heating] are not necessary in most areas of Ethiopia. Everything is natural because of the climate. In the future, all energy in Ethiopia is going to be provided by hydropower. Sustainability also means to make construction more Ethiopian in terms of material: not transporting materials from all over the world […]. Finally, sustainability means that it has to stand forever – at least 50 years. To be honest though, I have to say that 80% of what we are building is conventional because that’s how people want it, because it is modernity. In a hospital project, we are working with bamboo and mud, [but] these building materials are not considered forward thinking. [People] have used it for centuries in the country.

NB: Concrete is expensive in Ethiopia. So, if you built with alternative materials, wouldn’t that save in terms of investment cost?
RS: But what do you consider an alternative material? We suffer a lot with [bamboo and mud…]. I’ve seen many foreigners come and say, where is the bamboo? I think, because it’s Ethiopia,

because it’s Africa, people feel like it’s easier and cheaper. No it’s not! […] I’ve seen *so* much improvement [in the last 24 years, but] people want to do what they know. Engineers want to do what *they* know, for sure. We don’t even have the right testing facilities in order to test bamboo. So, when somebody comes to me and says that he wants to build sustainably with mud blocks, I say, sure, let’s do it… especially in smaller projects, that is not an issue. […] But you cannot tell me to build big projects with this kind of material […]. In terms of design, in terms of our engineers, in terms of our laborers, in terms of our production lines, Ethiopia is not ready.

NB: Many people her focus on building materials as an indicator for sustainable building. But is material really the issue in Ethiopia?
RS: It’s not. I am always challenging my [foreign] colleagues. I say: “What do you exactly mean when you say ‘sustainable construction’? In exactly *what* do you want me to build this column of a six story building out […]?” I would *love* to understand their mind-set. [Rather than worrying about materials, foreign experts] should come and improve principles [such as] orientation, building streets, or [how to] integrate community planning. That would be more useful. It’s not about material. I have seen so many projects like [this bamboo and mud hospital] fail. Of course, I would have *loved* for it to work out. But it can’t be 4’000 birr [± 200 €] per square meter. It *cannot be*! A simple [multi-storey] building without lifts or solar power kits costs 10’000 birr [± 500 €] per square meter.

NB: In order to make your projects sustainable, what do you do if material use is not the issue?
RS: […] This is what *I* do: Number one: I take projects […] where I know I can make a difference and where the clients accept me […]. Number two: We work around the natural system. We work on orientation *a lot*. If there are trees, we preserve them where we can. I *love* using sites, terrains. No deep cuts, no big walls, no nothing […]. And number three: We always introduce Ethiopian things […] – something that tells you that you are in Ethiopia, very specifically. [When it comes to not implementing sustainable building], I cannot say it’s all the client’s or the Government’s fault. *We* can make a difference… as architects.

NB: Can you tell me why almost every building in Addis has the same glass curtain façade?
RS: Unfortunately, […] people go to Dubai or to China where they see those and they say “I want that! I want the gold façade, I want the silver façade, etc.” Sometimes I feel like I should take one year off and make a study of how things can change… because I have a voice.

3.4 The book on sustainable building in Ethiopia

Scientific writing – be it in the shape of journal papers, theses, or books – is an essential part of how knowledge is produced and distributed today. While the range of this medium is generally limited to a small economic and intellectual elite, it is nevertheless a vital source of information (implicit or explicit) for researchers like us, coming from abroad. In order to find a scientific text, we could use as part of this research, we analyzed 25 recent papers and books on Ethiopian housing written by Ethiopians. To make the comparison, we analyzed the quantitative and qualitative consideration of “sustainable building” within each text. All of the 25 texts from 2002 until 2014 used the term sustainability. Fourteen of them used the word *sustainability* or *sustainable* exclusively as a synonym for “continuity”. Seven used sustainability as abstract concept, echoing definitions from Western resources. Only four were critically reflecting the concept of sustainability with regards to the Ethiopian context. In the end, we decided to include “Building Ethiopia - Sustainability and Innovation in Architecture and Design” as a source in our paper because it depicted a complex story on sustainable building in its own right. Interestingly, this part of the research revealed an

unexpected convention: It revealed that “sustainable building” did not seem to be an issue for critical discourse among Ethiopian scholars in the field of Housing.
There are seven chapters in “Building Ethiopia” edited by Cherenet and Sewnet, each devoted to one aspect of sustainable building: Urbanity, Connectivity, Temporality, Materiality, Economy, Technology, and Sociology. Each chapter contains essays, student projects, and photographic documentation produced by mostly Ethiopian members of the EiABC. The following excerpt was collected from six different texts, which were selected for being written by Ethiopian authors and for explicitly dealing with sustainability. The fragments are arranged to give an overview over the discourse on sustainable building going on in the book.

Zegeye Cherenet and Helawi Sewnet [19]: Architecture and urban design as disciplines in Ethiopia might be too young to respond to the current unprecedented demands, desires and expectations which are manifesting themselves through the rapid urbanization processes, hence demanding a proper media to establish a platform for intellectual and practical exchanges of ideas.

Zegeye Cherenet and Helawi Sewnet [20]: Almost all industries […] are dominantly run by imported skills, machineries, materials, and even means of processing […]. In the context of this book, sustainability is primarily about the NOW […]. The question is how does one find a balanced projection of tomorrow, which is coming to Ethiopia with additional 80 million people in 30 years time, while the existing is already challenged with the lack of basic services? How do we act NOW to address the NOW and project the positive TOMORROW? Sustainability (sustainable development) is not the usual ‘saving the dying planet’ slogan - it simply is sustaining life now and creating an environment where one can love life! […] Since 2006 the construction industry has become the fastest growing and the biggest employer in cities and second biggest industry in Ethiopia next only to agriculture. However, it is characterized by being excessively unaffordable, wasteful, import dependent, energy consuming, unbalanced and most of all un-contextual […]. Our architecture (especially of the global south) has to be well informed by the experiments of the ‘modern’ world so as not to repeat failures which neither nurture the present nor secure the future.

Ezena Yoseph [21]: The issue of sustainability can be approached from the social, environmental, and economic perspective. Taking local situation, capacity and inclination into account becomes imperative if we are to think of sustainability […]. Currently, the condominium accommodation is considered to be the most prominent approach. The attempt to meet the housing backlog in Addis is understandable. But the question of cost is still pending where the target group, the low-income group, cannot afford to own these units […]. The other issue is identity. Some areas that are very old parts of the city have developed their own identities with social-space patterns that have their own qualities. They are not appreciated and thus become targets of wiping out […]. Sustainability is also about caring for indigenous qualities.

Dirk Hebel and Elias Yitbarek [22]: Generally, in Addis Ababa, once the municipality permit is secured the architect is usually cut-off from the consecutive design and implementation processes and the final product and construction is largely left to the developer. Thus, at the moment, one can say that the design and construction of a building is not only ‘object- oriented’ but also ‘wallet-driven’.

Bisrat Kifle et al. [23]: Appropriate building technology is a concept that made its way into the construction industry in the early 20th century. It implies the use of locally available and produced building materials as well as easy and innovative construction techniques as a way of coming up with affordable and sustainable housing solutions.

Kalkidan D. et al. [24]: It is very important to select the appropriate building materials. When we choose materials, there are a number of factors that we should think about: what materials we use, how we use them, and where they come from all need to be considered among other things. In addition, minimizing the level of processing that the materials undergo keeps them simple and healthy, and preserves them as close to their natural state as possible, reducing pollution and embodied energy […]. Selection of materials should also be based on availability, constructability and the social, economic and climatic conditions of the site. And finally, those that are durable and long lasting are considered sustainable […].

4. Discussion

In the previous sections, we highlighted why it was necessary to conduct and present our research in the format of *baroque complexity*. We were also able to reveal a series of questions concerning sustainable building in Ethiopia which will help us to address the issue in the future.

4.1 Is "sustainability" appropriate to measure *good* building in Ethiopia?

According to the data collected, sustainable building is not realized in Ethiopia as it was intended by the West: as a holistic concept of social, economical, and ecological measures. Rather than that, sustainable building is either compromised because of economic pressure or it is reduced to the question of resource use leaving out social, aesthetic, and urban aspects. Is this to do with Ethiopia as a developing country? What, if we turn the question around and ask whether sustainable building as it was defined by the developed world is appropriate for the contemporary Ethiopian context? We already discussed how the appropriateness of a standard depends on *"the practical comparison of alternatives"* [9]. From the data presented in this paper, we learned that Addis Ababa evidently lacks alternatives in terms of building materials. The reasons for that are multi-faceted: forbidden natural building materials in Addis Ababa, a very limited formal building material market, and a bias towards traditional construction methods as backwards. Through our Ethiopian sources, we further discovered how limited budget, abilities, and knowledge further impede the implementation of sustainable building in contemporary Ethiopia. While informants and texts made it clear that sustainable building was not decided on the battlefields of material choice, the reality of "sustainable building" in Addis remains at the level of sustainable resource use e.g. through recycling, sustainable infrastructure, and local crafts.

We therefore conclude that "sustainable building" as a Western standard is is failing in the contemporary Ethiopian context. This conclusion leads us to a new fundamental question: How will it be possible to reach the previously stated sustainability goals of improving human life, replacing resources used, and preserving the ecosystem in Addis Ababa despite apparent obstacles?

4.2 Is there another option?

One chance certainly lies in Ethiopia appropriating the concept of sustainable building for herself instead of wasting money and time on trying to "enforce" a foreign concept through tools that are not appropriate for the context. This would require an honest discourse amongst Ethiopian building professionals and intellectuals.

If appropriating "sustainable building" is one option, changing the toolbox could be another option to reach *good* architecture. For example through a concept that is more responsive to the local context, more flexible, and more adaptable. De Laet and Mol suggest the concept of *fluidity* and to use it: *"[…] especially in cases of technologies transferred to, or designed for, so-called intractable places" [25].* For the purpose of this paper, we adopted this idea as a possible way of reaching sustainability goals in Ethiopia. But rather than *fluidity*, we will call it *urban resilience*[6]. If the goals of *improving human life*, *replacing resources used*, and *preserving the ecosystem* remain but the toolbox becomes more flexible and adaptive, we might as well achieve a more satisfying result. We claim that resilience as opposed to sustainability is much better suited to achieve a construction economy in Ethiopia that serves its society and environment rather than exploiting it. First of all, urban and architectural resilience is a young field and therefore has greater potential to be appropriated, innovated, and implemented by Ethiopian scientists, policy makers, and practitioners than sustainability. Secondly, resilience is much more suited to achieve sustainability goals because its core values are change and creativity, both of which are qualities that can without a question be attributed to Ethiopia's urban spaces.

4.3 What we learned

Admitting, we originally set out not only to discover what *sustainable building* in Addis Ababa means but also in order to generate future research ideas. What we realized is that *sustainable building* in Ethiopia is a very complex issue. Producing buildings that are "made to last" requires the integration of socio-cultural elements and urban design as much as creating an image of modernity and durability through architecture. Furthermore, we need to think about how to contribute to a professional and critical *Ethiopian* discourse rather than trying to implement "our" standards.

5. To conclude

With the help of two Ethiopian texts and two interviews, we were able to highlight the issue of sustainable building in Addis Ababa from the viewpoints of those affected while creating a base for professional discourse on the matter at a crucial point of Ethiopia's urban, social, and economic development. As of now, "sustainable building" is not appropriate as a standard which leads to a lack in professional discourse, to a over-simplified understanding of the matter, and worst of all to a practical non-implementation in reality. Following the documentation of this lack through our research, we were able to identify two paths towards a realization of sustainability goals in the Ethiopian building practice: One is the appropriation of "sustainable building" through a professional Ethiopian discourse. The other one is the complementation of the "sustainability toolbox" through the concept of urban and architectural resilience as a more flexible and adaptable approach to creating a healthy urban environment.

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Life cycle approach as a method for optimizing building services systems in extremely low energy buildings

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Summary

In this paper we use an evolutionary algorithm to optimize environmental impact in terms of greenhouse gas emissions (GWP_{100}, kg CO_2-eqv) from av ventilation ductwork system. The impacts is caused by embodied emissions from production of a ventilation ductwork and operational emissions from electricity used to power the ventilation fan and control equipment. The interrelationship between the duct dimension and building floor height, is used as a penalty function in the optimization model. One part of a ventilation ductwork system in an existing Passive house office building, serves as a case study.

Based on our case study, we conclude that duct dimensions in today's "green" office buildings, are optimal neighter in terms of GWP_{100} or operational electricity use. Compared to the original ductwork design, and a future optimistic and pessimistic el-mix scenario (0.200 and 0.300 kg CO_2-eqv/kWh_{el}) respectively, we are able to improve the environmental impact in terms of GWP_{100} (kg CO_2-eqv/yr) by 13% and 16%, and reduce the operational electricity by 22% and 25% over the next 30 years.

In general, some duct elements in the case ductwork should be increased for any electricity emissions scenarios in order to reduce the pressure drop and thus the environmental impact. Without penalty for large ducts, the optimization algorithm will gradually increase $Ø_{max}$ (max diameter) when the el-mix increases. Introducing such a penalty, the $Ø_{max}$ will be kept low except for "high" el-mixes. Thus, the complex interrelationship between the ventilation system and the building itself must be considered in future building design.

The most sensitive parameters to the result for an optimized solution are operational emissions from electricity, air flow rate, VAV standby power, years of operation and embodied emissions from ducts. To ensure a robust solution, great effort should be given to determine these parameters as correctly as possible before running the evolutionary optimization algorithm.

The life cycle approach in this study can contribute to a more holistic design of future buildings and their building services systems. However, lack of reliable Life Cycle Inventory data is the main hindrance for applying this LCA-method in research and engineering practice.

Keywords: LCI, electricity emissions, optimization, ventilation ductwork, specific fan power

1. Introduction

The development of low energy building concepts, such as Passive Houses and Zero Emission Buildings (ZEBs), has significantly reduced the energy needed for operation [1]. This improvement is achieved by increasing material use [2], making these buildings highly insulated and air-tight. To ensure thermal comfort and a healthy indoor air quality, a ventilation system with high airflow rates is imperative. However, environmental impact from buildings is not only caused by the operational energy consumption. Material and energy resources used to construct and maintain the building services, also contribute. When moving towards zero emission buildings, it is important to have a holistic verification of environmental performance from active and passive technology measures [3, 4]. This is important because a single, or unbalanced, improvement in the complex system that a building represents, might be counterproductive over the total life cycle. Furthermore, when moving towards the ambitious goal of a life cycle zero emission building, all emissions come into scrutiny.

Recently developed standards provide framework and calculation methods for life cycle assessment of buildings [5-7]. Nevertheless, the sensitivity of a building's environmental impact due to the complex interrelationship between the Heating, Ventilation, and Air-Conditioning (HVAC)-system and the building itself, is not well understood in a Life Cycle Assessment (LCA) perspective. In studies where LCA-methods are applied to building services systems [8-10], optimization techniques are rarely used. Due to available cost data, Life Cycle Cost (LCC)-methods are more widespread when designing and optimizing such systems [11-13]. In contrast, lack of reliable Life Cycle Inventory (LCI)-data is the main hindrance for applying the LCA-method in research and engineering practice [14, 15].

In the present work, we use an evolutionary optimization algorithm to assess greenhouse gas emissions impact (kg CO_2-eqv) caused by embodied emissions (EE) from the production of a ventilation ductwork system and operational emissions (OE) from the electricity used to power the ventilation fan. In this work, we use the environmental impact category is Global Warming Potential GWP_{100}, kg CO_2-eqv developed by [16]. In addition, operational electricity (kWh_{el}) is of interest.

Specific Fan Power (SFP) [17] is used in many European building codes to quantify maximal electrical energy (kWh_{el}) to overcome the pressure drop when transporting ventilation air. In general, small ducts reduce material use, but introduce a high pressure drop which increases fan power. Large ducts are more material demanding, but decreases the pressure drop and reduces fan power.

Maximum building footprint and height are normally defined by planning regulations. Most building owners will therefore strive for more rentable floors within the available height and volume. Thus, successful integration of pathways for energy efficient ventilation systems is challenging, and often involves compromises between architects, engineers, building owners, users and the legislative authorities. A crucial design constraint to be taken into consideration is that large vertical ducts demand more floor area for shafts, and horizontal ducts (> 400 – 500 mm) strongly influence the necessary floor height [18], and consequently need for additional external wall material (façade).

The purpose of this work is to answer the following research questions:

1. Are duct dimensions and fan power used in today's "green" office buildings optimal in terms of Global Warming Potential (GWP_{100}, kg CO_2-eqv)?
2. Given uncertainty in future (next 30 years) electricity production mix (kg CO_2-eqv/kWh_{el}), how much will the optimal duct dimensions change? (Material use vs. pressure drop/fan power)
3. When optimizing ventilation ductwork in terms of GWP_{100}, which parameters are more sensitive?

2. Methodology

Goal and scope: The main goal of this study is to apply LCI-data (ventilation ductwork components, control equipment, external wall) and an evolutionary optimization algorithm to minimize GHG emissions (GWP_{100}) caused by the ventilation ductwork system (EE and OE) in a Passive House office building.

Problem formulation:

Minimize GHG emissions:	GWP_{100} (kg CO_2-eqv/year) = Σ (EE + OE)
Subject to the constraints:	U_{max} for inlet ducts ≤ 3m/s (due to noise)
	25 mm duct insulation on duct surfaces (EE)
	4 W standby-power for each 6 VAV-regulators (OE)
Size limitations:	$d_{1\text{-}34}$ = Set of 15 standard circulare duct dimensions - [63,80,100,125,160,200,250,315,400,500,630,710,800,1000,1250]
	Set of LCI-data (EE) for standard ductwork components
Penalty functions:	If max duct dimension + 2x25 mm duct insulation > 500 mm, then add additional external wall area (EE) and heat loss (OE) through the extra wall area.

Evolutionary algorithm (EA): A genetic or evolutionary algorithm (EA) is a nature-inspired search method which applies principles of evolution to search through large sets of candidate solutions (solution space) to find the most "fit" or optimum solution [19]. Asiedu [12] applied this method when optimizing a HVAC duct system with respect to LCC.

The architecture of a spreadsheet makes it easy to set up models, and pre-programmed model-solving algorithms are able to generate solutions to the problem formulated in the spreadsheet [20]. We used Microsoft Excel and the accompanying evolutionary algorithm in the solver add-in, solver.xlam [21], as optimization tool. This solver handles MS Excel functions such as IF and LOOKUP (non-smooth "graphs" or discrete variables such as tables with ductwork components). Thus, the Excel spreadsheet and solver.xlam serves as a general purpose optimization modelling system, with a low entry level for both Researchers and Building Services Engineers.

Case building and ventilation ductwork: As a ductwork optimization case study, we used a part of the supply air ventilation ductwork in a 4 floor, 3500 m^2, office building located in Bergen, Norway. See Figure 1. The building is built in accordance with the Norwegian Passive House standard [22], and achieved Breeam-certification Excellent when completed in October 2013.

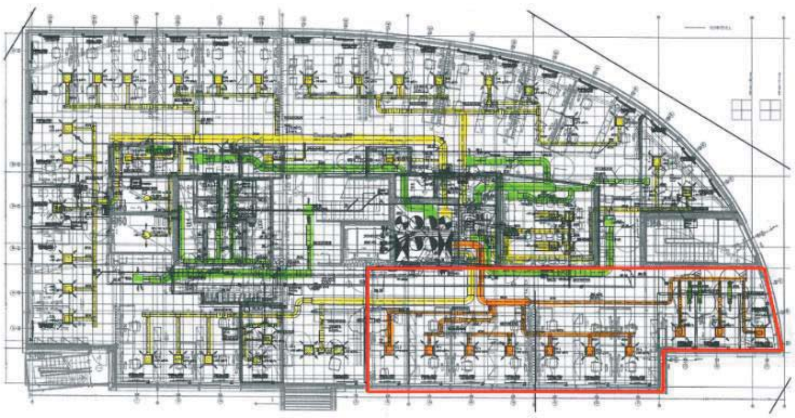

Figure 1: Building floor and ventilation duct layout. Supply air ducts in yellow and orange. Exhaust air ducts in green. Area of interest indicated by the red frame and orange supply air ducts. This area is approx. 150 m^2 with a façade length of 39 m of the building perimeter.

The air handling unit (AHU) is located on the roof. Pathways for the ventilation air runs through the plant and a vertical main shaft located in the middle of the building. From this shaft, 4 – 5 horizontal ducts enter each floor. The part of the ventilation ductwork system analysed in this work (red frame) consists of 10 paths, named A – J, starting from the vertical shaft and ending in the air inlet devices. A principle drawing of the supply air ventilation ductwork is shown in Figure 2. The EA uses the different duct elements (1 – 34) as decision variables, and chooses appurtenant ductwork components from "lookup-tables" based on up- and downstream duct diameters.

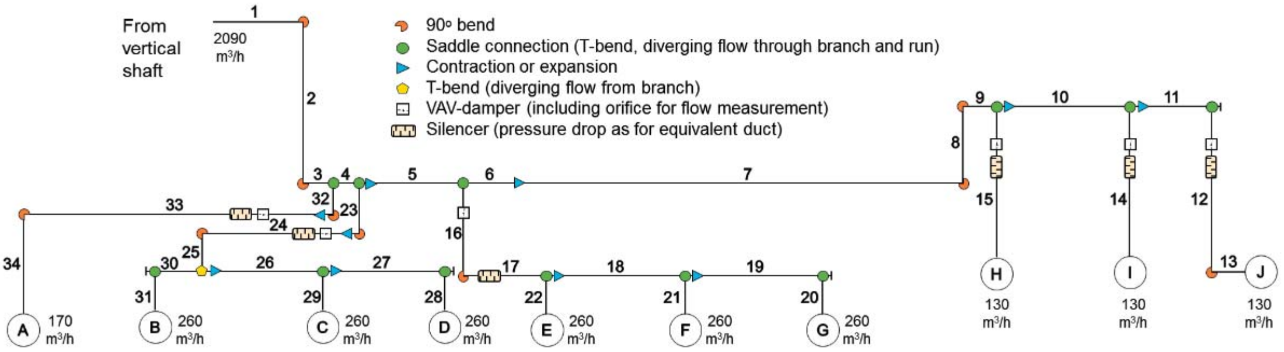

Figure 2: Duct layout – basis for the optimization problem. Ducts (1 – 34) and ductwork components used for pressure drop calculations, are indicated. The centreline distances in this ductwork are kept constant in the optimization, thus a large bend will reduce the straight duct lengths. The longest path (J) is 27.3 meters.

Pressure drop calculations: Friction factors for ducts and loss coefficients for fittings: T-bends, 90^0-bend, contractions and expansions, are calculated based on the formulas given in [23]. Loss coefficients for VAV-dampers are derived from curves in the manufacturer's technical leaflet [24]. The path with the largest pressure drop is the critical path. This path changes depending on VAV-damper position. However, control equipment for optimal VAV-damper positioning always keep the VAV-damper in the critical path open. For all practical purposes, an open VAV-damper is in reality placed in a 20^0 position. This introduces a pressure drop, but gives air flow controllability.

Fan power calculation: The pressure drop in the critical path is an input for calculating the necessary fan power for the different air flow rates. The pressure drop for the rest of the ventilation system (from AHU to where duct 1 enters the area of interest) is not taken into account in this study. Total fan efficiency (η_{tot_fan}) for a variable reference pressure controlled fan-system (hydraulic, motor and frequency converter) is given in [25], and is used to calculate the fan power. For 100% nominal air flow rate η_{tot_fan} = 64.3%. For 65% air flow rate η_{tot_fan} = 55.6% and for 20% η_{tot_fan} = 16.6% .

Embodied emission inventory (LCI-data): The life cycle phases included in this work are raw materials supply (A1) and manufacturing (A3) [6]. The expected service lifetime of the ducts and all components are set to 30 years in this study. (Fan operation and control equipment (standby power for VAV-motor) is included in operational emissions (B6).)

The Danish manufacturer Øland's data sheets for standard ventilation ducts and ductwork components [26] are used as foreground inventory data. This data has been systematized (material composition, dimensions and weight) by Schau [27] for straight circular ducts, 90^0-bend/elbows with radius equal to diameter, T-bend/saddles ("branch connections"), silencers and air inlet devices. Data for contractions and expansions are used for pressure drop calculations, but embodied emissions are assumed to be negligible for these components in this study.

The Ecoinvent database v3.1 [28] is used for background inventory data and SimaPro v8.05 [29] as the life cycle modelling tool. The production of the components is based in Europe. Embodied emissions for the VAV-regulators and VAV-motors are used as presented by Schau [27].

Ductwork insulation used in this study is 25 mm glass wool mat and 0.018 mm aluminium foil. The Ecoinvent v3.1-processes “Glass wool mat CH production” and “Aluminium, wrought alloy GLO” is used for embodied emissions.

Embodied emission for the external wall is based on Sørnes [30]. The material composition is timber, gypsum, insulation, steel screws, plastic and a fibre cement facing tile.

Only embodied emissions from the components installed within the red zone (Figure 1) are included, emission from AHU, vertical ducts and shafts is not considered in this work.

Heat loss through external wall: In case of large duct dimensions (we use >500 mm in this study), the optimization model adds additional external wall material and heat loss as a penalty-function. To estimate average heat loss through the additional wall, we used the dynamic building energy simulation model from a ZEB-concept office building [31]. Normalized to 1 m^2-façade, the additional net heat demand caused by a small increase in floor height is estimated to 12.5 kWh/m^2 wall per year. Window area is kept constant. This heat is assumed produced with electricity in a heat pump with a coefficient of performance (COP) =3.

Operational emissions from electricity (“el-mix”): “Little is known about the environmental implications of a widespread, global shift to low-carbon electricity supply infrastructure” [32]. However, five scenarios for greenhouse gas emissions from electricity production (kg CO_2-eqv/kWh_{el}) in Europe in a long term perspective (2010 – 2050) are presented by Graabak [33].

Depending on the level of technology development, public attitude, changes in user behaviour, introduction of renewables and use of coal and gas, the scenarios for the next 30 years period (2015 – 2045) give approx. 0.200 kg CO_2-eqv/kWh_{el} for most optimistic scenario and 0.300 for the most pessimistic [33]. Given the uncertainty in future el-mix, our optimizations are performed with varying el-mixes (kg CO_2-eqv/kWh_{el}).

Hours of operation at different air flow rates in an office building with VAV-regulators, are challenging to predict. The actual ventilation system is designed for a high, nominal air flow rate to ensure thermal comfort when there is a cooling demand. Due to variations in occupancy, 30 – 70% in the normal office building working hours, the air quality will normally be satisfactory with much lower air flow rates than the nominal [34].

The Norwegian Passive house standard [22] specifies 3120 working hours per year (12 h/day / 5 days/week / 52 weeks/yr). Within these hours, the air quality requirements should be met. Outside these hours (5640 h/yr), a minimum air flow rate is required. To simplify the calculations, we assume 3 different air flow rates and hour or operation, respectively: 100% air flow rate 1000 h/yr; 65% air flow rate 2120 h/yr; 20% air flow rate 5640 h/yr.

Parameter sensitivity: The optimization model involves several parameters that can influence the result in terms in terms of GWP_{100}. We use ±30% to examine how much an optimized result will change depending on variations in the different parameters.

3. Results

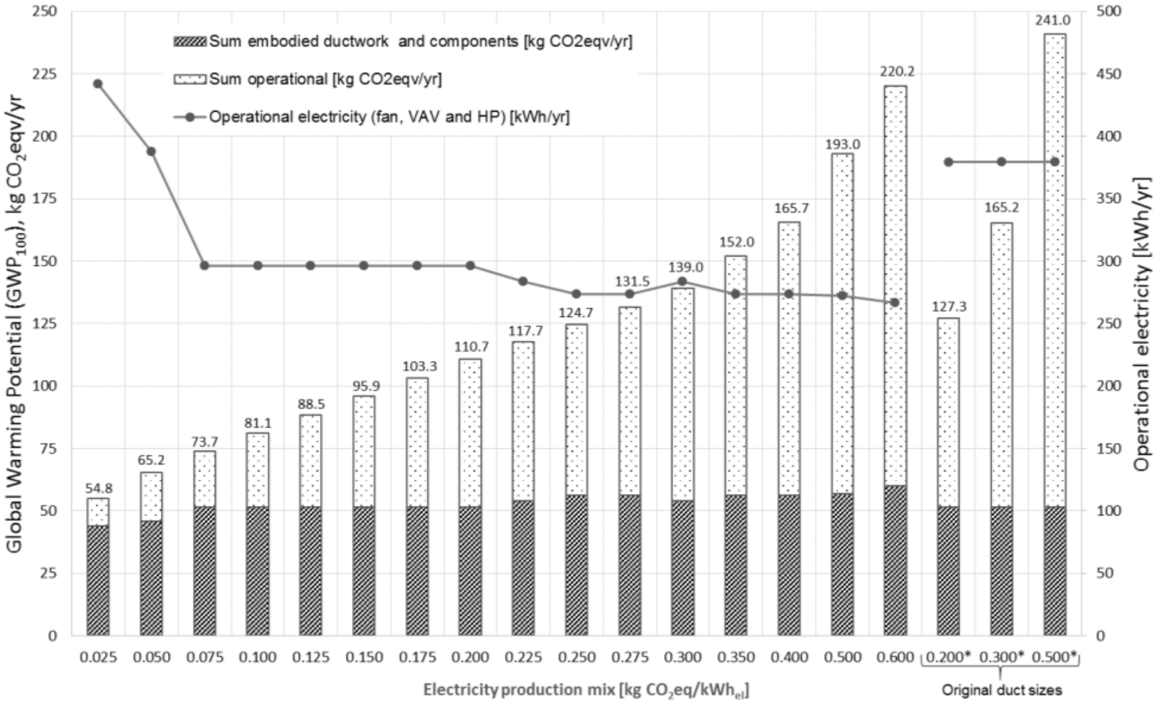

Figure 3: Environmental impact (GWP_{100}) from ductwork optimized with different el-mixes. The maximum diameters range from $Ø_{max}$=315 mm + insulation for el-mixes 0.025 and 0.050, to $Ø_{max}$=500 mm + insulation for el-mix 0.600. For all other el-mixes, $Ø_{max}$=400 mm + insulation. Penalty are given for duct + insulation >500 mm.

Figure 3 shows the results from optimizing the case ventilation ductwork in terms of global warming potential (kg CO_2-eqv/yr). Electricity production mixes ranging from 0.025 – 0.600 kg CO_2-eqv/kWh_{el}. The three columns to the right represent the original ductwork, calculated with 0.200, 0.300 and 0.500 kg CO_2-eqv/kWh_{el}. The lower part of the columns (dark grey) is total yearly embodied emissions from ductwork and components, and the upper part is operational emissions caused by electricity use. The total (EE + OE) is indicated above the columns. The black curve shows the operational electricity use (kWh/yr on right y-axis) for the different optimized solutions.

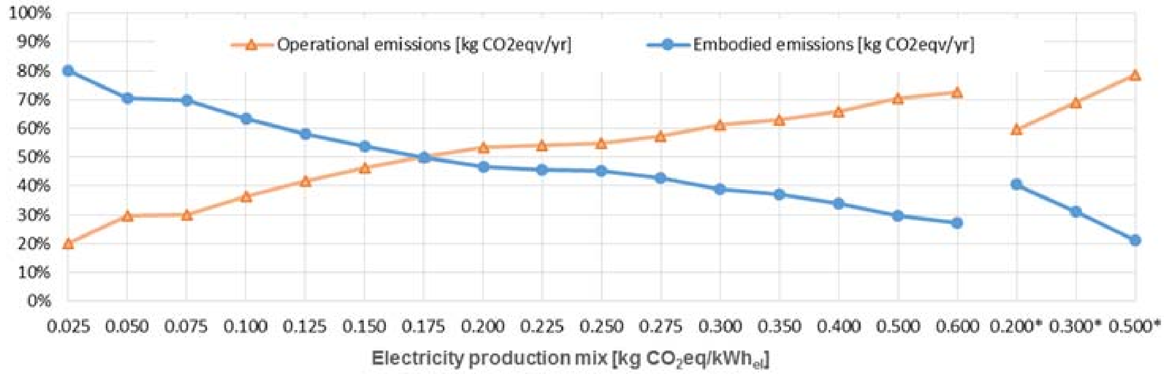

Figure 4: Relative share [%] of embodied (EE) and operational (OE) emissions. From results in Figure 3.

From Figure 4, we see that the relative share of EE and OE changes depending on the el-mix. For an el-mix of 0.175 kg CO_2-eqv/kWh_{el}, the share is 50/50% between EE and OE. Assuming a future “clean” el-mix, the optimization algorithm prefers 80% EE and 20% OE in order to minimize the environmental impact. For the pessimistic el-mix scenario (0.300 over the next 30 years), the minimum environmental impact is achieved with 39% EE and 61% OE. For the optimistic scenario (0.200), the result is 47% EE and 53% OE. However, the operational electricity will be different.

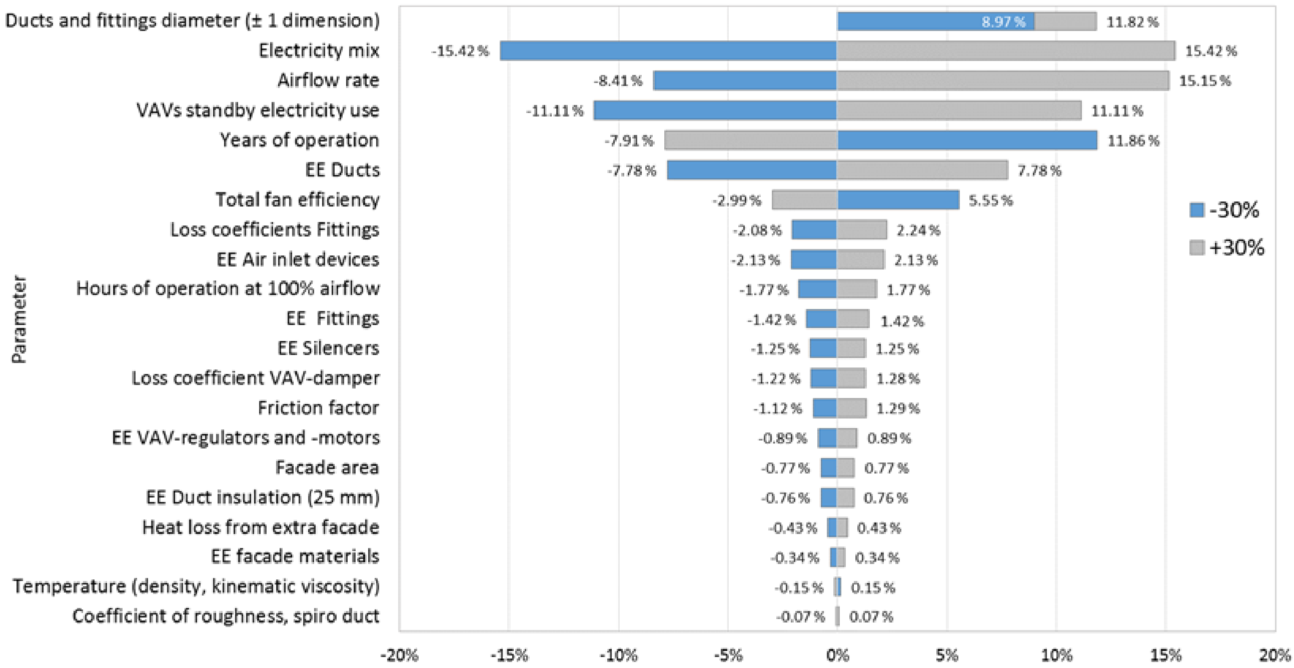

Figure 5: Parameter sensitivity (±30%) relative to baseline 113.6 kg CO_2-eqv/yr (0%) optimized with an electricity mix of 0.200 kg CO_2-eqv/kWh$_{el}$. Penalty for duct diameter + insulation > 400 mm. ($Ø_{max}$=400 mm)

For Figure 3, we used a penalty for duct + insulation > 500 mm. For all the el-mixes, except 0.600, the optimization algorithm kept $Ø_{max}$ below this to avoid the penalty. To illustrate the parameter sensitivity for a case where additional external wall (façade) is added, Figure 5 is based on a ductwork optimized with a penalty for duct + insulation > 400 mm and an el-mix of 0.200. For these two "penalty" situations, the maximum duct diameter for the optimized ductworks becomes identical.

When optimizing ventilation ductwork in terms of GWP_{100}, Figure 5 shows that the optimized solution is more sensitive to changes in el-mix, air flow rate, VAV standby power, years of operation and embodied emissions from the straight ducts. Uncertainty in amount of additional façade area only changes the environmental impact by less than 1%. To ensure a robust solution, great effort should be given to determine these parameters as correctly as possible before running the optimization.

4. Discussion

In order to reduce pressure drop and operational electricity, the optimization algorithm quickly prefers increased diameters for all ducts when the el-mix increases, see Figure 3. In our case study, the preferred combinations of ducts remain identical for el-mixes ranging from 0.075 to 0.200. Differences in environmental impact are then due to OE from electricity (fan and VAV-motors). In our case, this means that the optimized ductwork combination is relatively robust to the great uncertainties in future el-mix scenarios. For future research, it would be an interesting task to examine whether intermediate duct dimensions would be even more beneficial than today's standard dimensions.

Due to the introduced penalty for large duct diameters and duct insulation, the optimized results choose $Ø_{max}$=400 mm + insulation for a wide range of el-mixes. When running the optimization without this penalty, we will in general see that $Ø_{max}$ increases by 1 – 2 dimensions. However, large ducts will increase heat losses/gains between the supply air and the different building zones. Without duct insulation, the changes in supply air temperature could be a problem. Thus, the interaction between the building and its ventilation system must be taken into consideration when designing and optimizing future buildings.

In Figure 3 we see high operational electricity for the two “cleanest” el-mix alternatives. For the other el-mixes, the optimization algorithm prefers to decrease the pressure drop and electricity use, introducing more materials (larger ducts). A reduction in SFP is often considered an important measure in extremely low energy buildings. Within the system boundary of this work, additional attempts to reduce operational electricity for an optimized duct combination, will increase the total environmental impact (GWP_{100}). Thus, when the goal is to minimise the environmental impact in terms of GWP_{100}, reducing SFP can prove to be the wrong measure. However, compared to the original case ductwork, the pressure drop and SFP clearly should be reduced.

Figure 5 shows high sensitivity to VAV-motors’ standby power. In our duct system (Figure 2), we have 6 VAVs all with 4 W standby power. In total, this is equivalent to 210 kWh_{el}/yr, and thus represents the major contribution to the operational energy for most el-mix cases. For example, an el-mix of 0.200: 29% is due to necessary fan power and 71% is standby power from the VAVs. Thus, the environmental impact from the control equipment cannot be neglected when optimizing ventilation ductwork systems.

Figure 5 illustrates low sensitivity (< 5%) for several parameters. However, uncertainty in many parameters could accumulate and change the optimum duct combination. These uncertainties can be addressed using a Monte Carlo technique in combination with the evolutionary optimization algorithm. In this way, the most robust duct combination over the life time could be determined.

So far, our embodied emissions inventory (LCI-data) considers only a few of all the life cycle phases. Additional emissions from the construction phase, maintenance, replacement and end-of-life treatment could change the optimal duct combination. However, in our case the sensitivity for embodied emissions from the ductwork do not change the solution more than approximately 8%.

30 years is a normal service lifetime for ventilation ductwork. However, in practice the lifetime varies greatly. For AHU the functional lifetime is estimated to 16 - 20 years, building control and automation equipment 11 - 15 years and for ductwork 21+ years [35]. As expected, Figure 5 shows high sensitivity to lifetime. Thus, a sustainable ventilation ductwork design must promote a long lifetime.

5. Conclusion

This case study shows that a ventilation ductwork system can be optimized in terms of of GWP_{100}, (kg CO_2-eqv) by use of LCI-data on component level and the evolutionary algorithm in MS Excel’s add-in solver. However, it is crucial that the combined environmental impact caused by the complex interrelationship between ductwork, fan, control equipment’s standby power and the building itself (building floor height) is taken into account. The life cycle approach in this study can contribute to a more holistic design of future buildings and their building services systems.

1) Based on our case study, we conclude that duct dimensions in today’s “green” office buildings, are optimal neighter in terms of GWP_{100} or operational electricity use. Compared to the original ductwork design, and the optimistic and pessimistic el-mix scenario (0.200 and 0.300) respectively, we are able to improve the environmental impact in terms of GWP_{100} (kg CO_2 eqv/yr) by 13% and 16%, and reduce the operational electricity by 22% and 25% over the next 30 years.

2) In general, some duct elements should be increased for any el-mixes in order to reduce the pressure drop and thus the environmental impact. Without penalty for large ducts, the optimization algorithm will gradually increase $Ø_{max}$ (max diameter) when the el-mix increases. Introducing such a penalty, the $Ø_{max}$ will be kept low except for "high" el-mixes. Thus, the complex interrelationship between the ventilation system and the building itself must be considered in future building design.

3) Figure 5 clearly shows the most sensitive parameters to an optimized solution: *el-mix, air flow rate, VAV standby power, service lifetime/years of operation, embodied emissions from straight ducts*. To ensure a robust solution, great effort should be given to determine these parameters as correctly as possible before running the evolutionary optimization algorithm.

6. Acknowledgements

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Life cycle assessment of small road bridges: Implications from using biobased building materials

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Summary

Environmental impacts such as climate change are threatening humanity's future and quality of life. The relatively high contribution from the building sector to the global environmental impacts and energy consumption means it is under pressure to decrease the impacts from construction projects. Previous research has been focused on buildings and energy efficiency and their impacts, but infrastructure projects are seldom analysed. A shift to bio-based products and bioenergy is often found favourable when using Life cycle assessment (LCA) climate impacts compared to available alternatives. A life cycle assessment has been carried for two alternative designs for a small road bridge; a concrete and a wooden superstructure. A service life of 80 years including maintenance has been assumed, and since both designs have the same usable road area, one full bridge has been set as functional unit. The Product Category Rules (PCR 2013:23) for bridges and elevated highways was followed. The results show that the wooden structure design has a lower environmental impact than the concrete for all the evaluated impact categories, being material production and maintenance the largest contributors. Furthermore, the major contributions come from manufacturing of steel components, both for maintenance and production. The higher amount of transport required to prefabricate the elements in the wooden bridge does not seem to affect the result, while the environmental impact contribution from maintenance is comparable for both designs. Further research should include efforts to include the end-of-life stage and effects from carbon storage in wood products and concrete carbonation.

Keywords: Life Cycle Assessment; Small road bridge; Wooden bridge; Concrete bridge; Dynamic LCA.

1. Introduction

Climate change and other environmental impacts pose a significant threat to humanity's future and our capacity to assure a life quality for future generations comparable to ours. This is why there is an urgency to mitigate these impacts, especially climate change [1]. The construction sector contributes with around 19% of the global greenhouse gas emissions [2], which is why there is an urge to reduce the environmental impact from construction projects.

Life Cycle Assessment (LCA) is a well-established tool which is extensively applied to compare the environmental impact of different products and services, providing decision-makers with valuable information which can be used to improve the environmental profile as early as in the design phase. However, the use of LCA in the construction sector has been concentrated mainly in residential buildings and to some extent in commercial buildings or road construction [3]. The amount of literature and research studies that apply LCA in bridges is very limited, and the environmental profile of different structures is very case-specific since bridges are complex structures and the results are highly sensitive to certain methodological choices [4].

Some industrial sectors are increasingly considering the forest not only as a source of renewable raw materials, but also as an alternative to improve the environmental profile of their products [5], and the construction sector is among those. Most of the existing studies where different materials are compared for bridge structures focus on comparison between steel and concrete since heavy-duty cases such as railroad bridges are not built with timber structures [4]. The functional unit is highly influential to the results when LCA is used to compare timber, concrete and steel structures [6]. On the other hand, the life cycle stages that contribute the most to the climate impact of bridges are the manufacturing of materials and the maintenance, while the end-of-life impacts introduce important uncertainties [7]. The aim of this study is to use LCA to compare the environmental impact of two common types of small road bridges, wooden and concrete. For this, an existing road bridge in the municipality of Åstorp in Sweden has been used as a case study.

2. Methodology

3.1 Studied bridge designs

This study focuses on a small bridge built in Åstorp decades ago, located in Malmövägen over the railway line Åstorp – Kattarp. The old bridge was rebuilt in spring 2014 with a new wider concrete slab, with two lanes and designed to handle heavier vehicles under the classification BK 1. The materials and activities needed for the construction of the concrete bridge have been provided by the designers and contractors, while the wooden bridge was generated by the industrial suppliers Moelven Töreboda and Martinsons Träbroar. Some technical specifications for the bridge are presented in table 1, while more detailed information about the design can be found in the original project's background report [8]. The existing foundations were used and the construction work consisted only of a replacement of the bridge superstructure.

Table 1: Technical specifications of the Åstorp bridge

Parameter	Specification
Theoretical span	15.07 m (one span)
Free bridge width	7.5 m

Bridge area	118 m^2
Traffic load EG A / B	Vehicles on entire bridge 740/180 kN, Vehicle on middle 1050/300 kN
Technical life	80 years
Coating	Waterproofing 5 mm waterproofing mat
Wear layer	40 mm ABS <16 / B 70/100
Binder layer	40 mm AB> 11 / B 70/100
Protective layer	25 mm ABT 8 / B 70/100

3.1.1 The concrete bridge

The new bridge superstructure is a simply supported slab of concrete with a span of about 15 meters; a concrete superstructure which can be considered as representative for Swedish road bridges. The bridge was cast on site, on existing foundations. Its building height was slightly squeezed together because of limited height, which means more steel and less concrete than normal. The bearings, expansion joints at ends, asphalt surfacing and railings are included in LCA calculations. The maintenance operations for the concrete bridge include concrete repairs to the edge beams, repair of the expansion joints, replacing the asphalt, replacing the waterproofing, replacing the bearings and replacing the railing. The assumed maintenance operations and their frequency are displayed in table 2, while figure 1 shows details for the concrete bridge design.

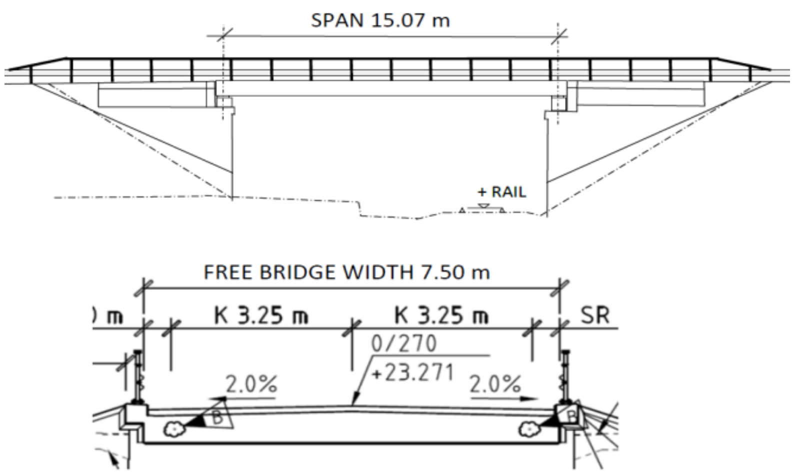

Fig. 1 Details of the concrete bridge; elevation (above) and section (below)

Table 2: Maintenance activities for the concrete bridge

Activity	Frequency (years)	Times in 80 years
Edge beams, concrete repair> 30-70 mm, repairing damage to the edge beams, the top and outside, 1/10 of the length	30	2
Expansion joints reparation	30	2
Asphalt replacement	20	3
Waterproofing mat replacement	40	1
Replacement of bearings	50	1
Railings replacement	40	1

3.1.2 The alternative wood design

Martinson Träbroar and Moelven Töreboda designed a wooden slab as an alternative to the new concrete slab in Åstorp, and provided the appropriate detailing. The height of this wooden slab is slightly higher than for the concrete bridge. The wooden bridge consists of a pre-stressed wooden slab of glulam from softwood, and provided with the same coating as on the concrete bridge. The bridge is supplied in blocks and the prestressing bars are stressed on site with a hydraulic pump. The sides of the slab are clad with unpainted pressure impregnated panels, while the underside is painted. The railing has the same rating as the railing of the concrete bridge, but designed with tubes, a common choice by Swedish wooden bridge suppliers. The expansion joint is designed with steel plates, differing from the concrete bridge, also affecting the maintenance. This maintenance includes measures such as re-stressing of the bars, replacing the asphalt, replacing the waterproofing, replacement of the expansion joints, replacement of the rubber bearings, replacement of railings, replacement of the panel and repainting the underside. The assumed maintenance operations and their frequency are displayed in table 3, while figure 2 shows details for the wooden bridge design.

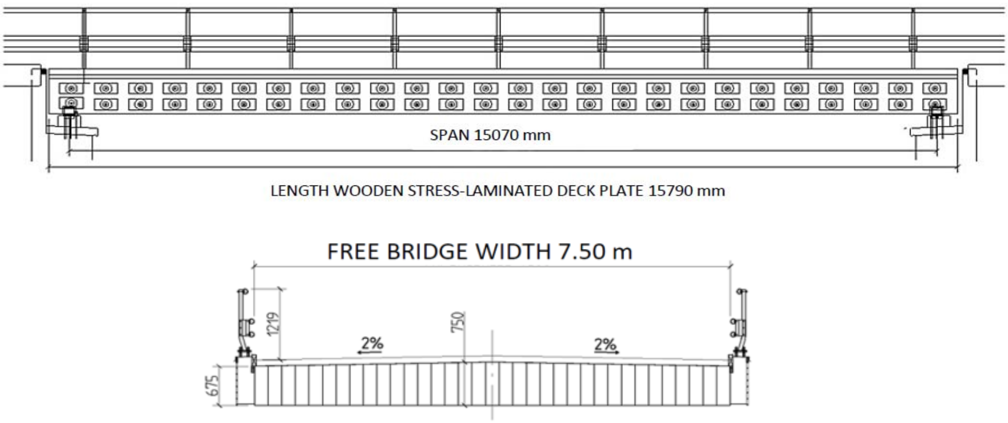

Fig. 2 Details of the wooden bridge; elevation (above) and section (below)

Table 3: Maintenance activities for the wooden bridge

Activity	Frequency (years)	Times in 80 years
Restressing of the bars	27	2
Asphalt replacement	20	3
Waterproofing mat replacement	40	1
Expansion joint replacement	30	2
Rubber bearing replacement	40	1
Railings replacement	40	1
Panels replacement	40	1
Repainting of slab underside	40	1

3.2 Life cycle assessment

The Product Category Rules (PCR) “Bridges and elevated highways” (UN CPC 53221) [9] have been followed for the life cycle assessment in this study. Nevertheless, the functional unit has been defined as one road bridge superstructure lasting for 80 years, contrary to the one meter bridge per year suggested by the PCR. Figure 3 displays the system boundaries of this study. The calculations did not include connecting road, traffic or the possible diversion of traffic during construction or maintenance work, filling, abutments and the foundations, since the bridge has been built over the old foundations. The assessment includes materials for the construction of the bridge, the energy used for construction and prefabrication of building elements, the transport of materials to the building site and factories, as well as maintenance work. Demolition and disposal have been excluded from the study.

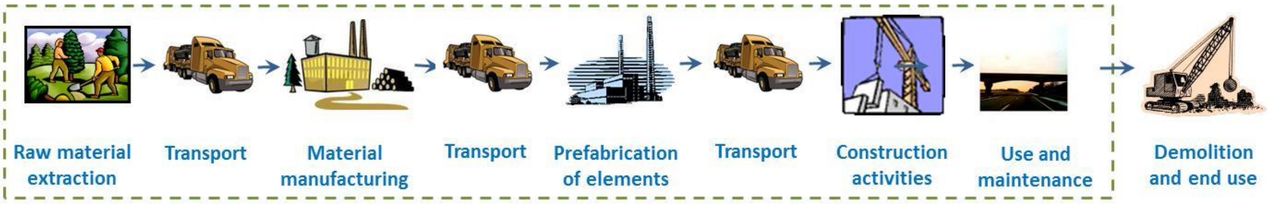

Fig. 3 System boundaries for the LCA and delimitation of included processes and activites

Most of the LCI data was taken from the Ecoinvent 3.0 database with the cut-off allocation approach and from relevant Environmental Product Declarations (EPD). The main differences with the study carried for the original report [8] are the use of more recent EPDs for cement production in the concrete bridge and glulam production for the wood bridge, also the use of Ecoinvent data for the wood bridge instead of data from the Network for Transport Measures-NTM. The Ecoinvent datasets used for product manufacturing processes taking place in Sweden were modified so the electricity demand is supplied by the Swedish electricity mix, while the European electricity mix was used when the production takes place in Europe. An outline of the assumptions and data sources used to model all the processes in the system is presented in table 4, and further information can be found in the background report and its appendixes [8]. Finally, it should be mentioned that both Martinsons and Moelven’s wood products are made from sustainable forestry certified by the Forest Stewardship Council (FSC) and the Program for Endorsement of Forest Certification (PEFC).

Table 4 Key assumptions and data sources for the LCA model used in the study

Process	Key assumptions	Data source
Production of steel components	Unmodified from Ecoinvent Production of steel and metal working to form	Ecoinvent 3.0 data: Steel, chromium steel 18/8, hot rolled {RER}; Metal working, average for steel product manufacturing {RER}
Production of galvanized steel	Unmodified from Ecoinvent Production of steel and metal working to form	Ecoinvent 3.0 data: Steel, low-alloyed, hot rolled {RER} Metal working, average for steel product manufacturing {RER}
Production of stainless steel	Unmodified from Ecoinvent Production of steel and zinc coating	Ecoinvent 3.0 data: Steel, chromium steel 18/8, hot rolled {RER}; Zinc coat, pieces {RER}
Production of sawn timber	Unmodified EPD from several sawmills average)	”Miljöfakta om trä och träprodukter” Ref: kontenta 0009032, SP-INFO 2000:09032
Sawn timber treatment	Ecoinvent data, modified with Swedish electricity mix	Wood preservation service, sawn wood, {Ad to SE}
Production of glulam	Unmodified EPD from Martinsons Såg AB	“Limtre”, NEPD-346-236-NO
Production of paint	Ecoinvent data, modified with Swedish electricity mix	Ecoinvent 3.0 data: Alkyd paint, white, without water, in 60% solution state {Adapted to SE}

Production of primer for wood exteriors	Material inputs from product sheet (content), used Ecoinvent data for all	Product declaration (Beckers, 2013). Content: 20% oil solvent, 7% acrylate, 7% linseed oil, 45% water, 20% Titanium dioxide, 7% Dolomite.
Production of bitumen	Ecoinvent data, modified with Swedish electricity mix	Ecoinvent 3.0 data: Bitumen seal, V60 {Ad to SE} Bitumen adhesive compound, cold, at plant {Ad to SE}
Production of asphalt	Ecoinvent data, modified with Swedish electricity mix	Ecoinvent 3.0 data: Mastic asphalt {Ad to SE}
Production of rubber	Ecoinvent data, modified with Swedish electricity mix	Ecoinvent 3.0 data: Synthetic rubber {Ad to SE}
Production of cement	Unmodified EPD from Cementa AB (Heidelberg cement group)	EPD-HCG-20140186-CAD1-EN Portland Cement CEM I 42.5 N-SR 3/MH/LA (Anläggningscement Std P)
Production of reinforcing steel	Ecoinvent data, 99% from recycled steel, from Poland	Ecoinvent 3.0 data: Reinforcing steel {RER}
Casting of concrete	Ecoinvent data, modified with Swedish electricity mix and recipe from suppliers	Ecoinvent 3.0 data: Concrete, high exacting requirements {Adapted to SE}
Production of epoxy resin	Unmodified from Ecoinvent	Ecoinvent 3.0 data: Epoxy resin, liquid {RER}
Production of silicone	Unmodified from Ecoinvent	Ecoinvent 3.0 data: Silicone product {RER}
Production of Teflon	Unmodified from Ecoinvent	Ecoinvent 3.0 data: Polyvinyl fluoride, film {US}
Production of brass	Unmodified from Ecoinvent	Ecoinvent 3.0 data: Brass {CH}
Production of plywood	Unmodified from Ecoinvent	Ecoinvent 3.0 data: Plywood, for indoor use {RER}
Production of draining lining	Unmodified from Ecoinvent	Textile, jute {IN}
Transport for the wood bridge	Unmodified from Ecoinvent	Road transport, truck with trailer: Lorry >32t EURO4 for transport of crane and prefabricated elements to site Lorry 16-32t EURO4 all other transports
Transport for the concrete bridge	Unmodified from Ecoinvent	Ecoinvent 3.0 data: Light commercial vehicle for DAB and Stainless steel; Inland waterways barge tanker (RER) for reinforcement steel and Plywood; Lorry 16-32t EURO4 for all remaining transports
Construction activities	Only operation of machinery on site Unmodified from Ecoinvent	Diesel, burned in building machine {GLO}
Prefabrication of elements	Only electricity, Ecoinvent 3 Swedish mix	Electricity, medium voltage {SE} (from 2008, extrapolated and adjusted to 2014)

As for the impact assessment, CML IA baseline was used to assess global warming potential, abiotic depletion potential, ozone layer depletion, photochemical oxidation, acidification potential and eutrophication potential. Human and ecotoxicity indicators have been left out due to lack of robust data for key materials and processes. The product system does not include any land transformation based on the definition of land transformation in the Product Environmental Footprint (PEF) guidelines. Consequently, biodiversity indicators have not been considered either.

3. Results

Figure 4 displays the global warming potential results for the evaluated designs, showing the contribution from all the life cycle stages included in the analysis. Then, figure 5 shows a percentage comparison between the resulting environmental impacts for both designs for all the impact categories evaluated. Finally, the results are summarized in table 5. The results differ from the results in the background report in some ways. The transport for the wood bridge is higher for this study since Ecoinvent data has been used. Meanwhile, the climate impact from the material manufacturing for the concrete bridge has decreased because a more recent EPD for cement has been used, same as the manufacturing of the wooden bridge due to the use of an updated EPD for glulam production. The used of more updated data has affected similarly most of the impact categories results in table 5.

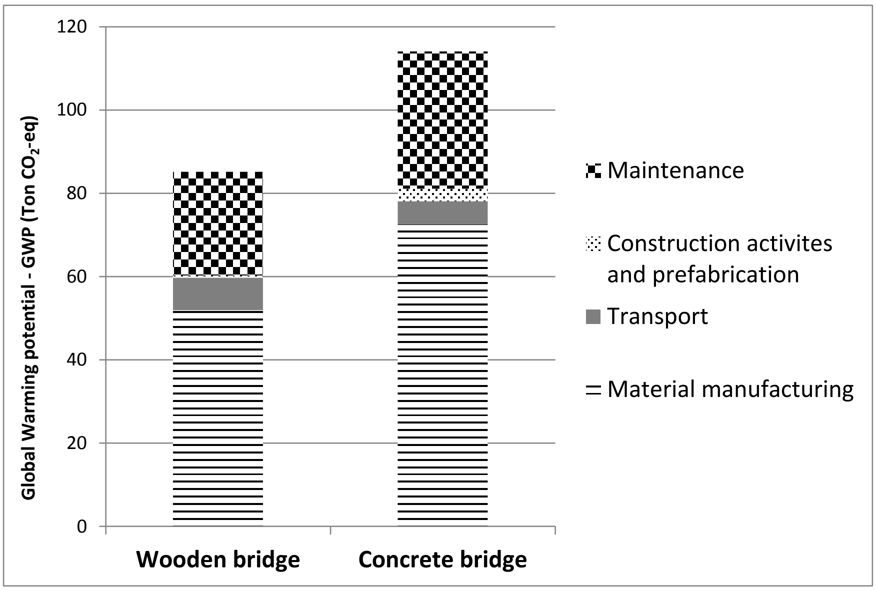

Fig. 4 Results for the global warming potential (GWP) per life cycle stage for the wooden and concrete bridge

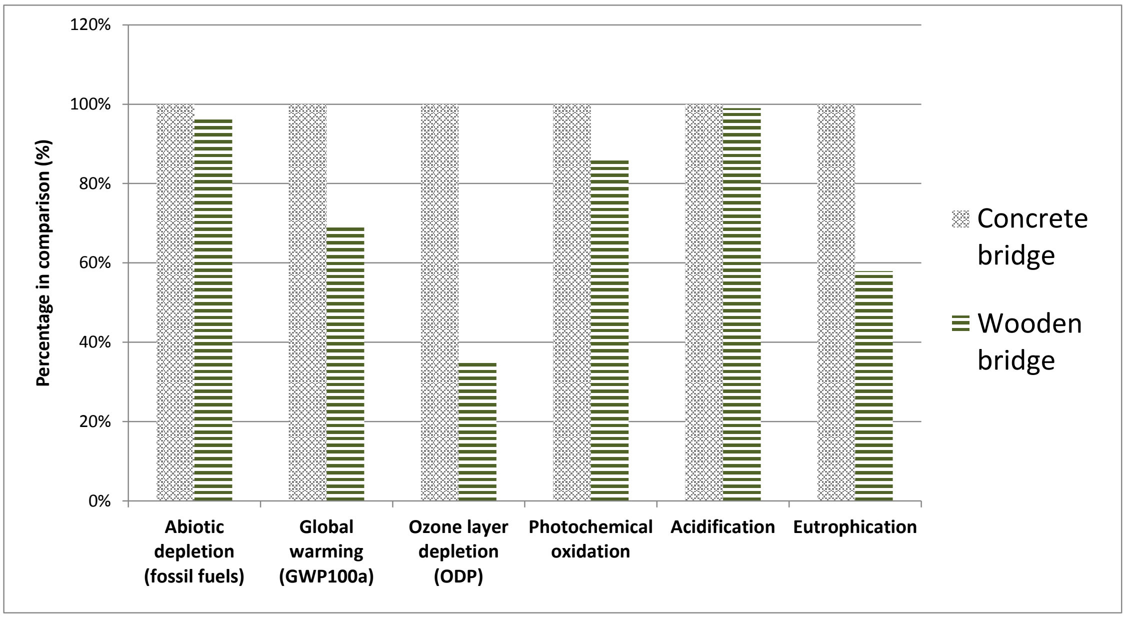

Fig. 5 Results for all impact categories studied, compared in terms of percentage

Table 5 Outline of the LCA results for the concrete and wood designs, using the CML baseline method

Impact category	Unit	Concrete bridge	Wooden bridge
Abiotic depletion potential (Fossil)	MJ	1377019.90	1328467.72
Global Warming Potential (GWP)	kg CO_2 eq	114669.20	79428.44
Ozone layer depletion (ODP)	kg CFC-11 eq	1.54E-02	5.43E-03
Photochemical oxidation	kg C_2H_4 eq	37.72	32.70
Acidification potential	kg SO_2 eq	523.51	518.33
Eutrophication potential	kg PO_4^{---} eq	230.35	133.50

4. Discussion

The results in figure 5 clearly show that the wood design performs better for all the evaluated environmental impact categories for the system studied. The results for acidification, abiotic depletion potential and photochemical oxidation are somewhat comparable. On the other hand, the gap is more substantial for eutrophication and global warming potential where the impact from the wood design is around 60% of that for the concrete. The gap is even more dramatic for the ozone layer depletion, where the result for the wood design amounts for about 40% of the impact from the concrete design. Since both designs have the same functionality in terms of effective road area, this means a wood design is environmentally preferable.

A closer look to the production phase reveals that for the wood design, the production of steel clearly dominates the result for most of the impact categories. Meanwhile, the contribution for the impacts from the concrete bridge is more even, dominated equally by the production of concrete, steel components and reinforcement steel. The contribution from asphalt and bitumen is not relatively important for either design in terms of percentage of the total results. The same can be said about the production of glulam for the wooden design. Based on all this, it is safe to say that the highest potential for reducing climate impact in both designs can be found in the production of steel, whether it is for reinforcement or other types of components.

Given the urgency of climate change action, it is worth having a closer look to the role of all the studied life cycle stages in the study. The production of materials clearly dominates the result for both bridges, while the maintenance has an important contribution as well. The production of steel contributes notably for both alternatives, as discussed previously. One interesting finding is the somewhat low contribution from transport for the wooden bridge, even as most of the bridge elements were prefabricated in a factory in Töreboda. The transport for the wood design is double so much than for the concrete design, but since the contribution from transport is relatively low the effects from the additional transport are not very noticeable.

It is common, at least for buildings, to believe that wood construction requires more maintenance if compared to concrete. Therefore it is an interesting finding that the maintenance for the concrete bridge is slightly higher than for the wooden bridge. The reason for this is that the maintenance required for both designs involves chiefly replacement of asphalt, bitumen, rubber and steel parts, and in similar amounts and intervals. The difference among the designs lays in the maintenance required for the beams in the concrete bridge and the exterior panels for the wood design, and given that the climate impact from glulam panels is relatively low, the total result for the maintenance is higher for the concrete bridge.

It can be argued that the results could be different if the end-of-life stage is to be included in the system boundaries of the study, and thus its omission may affect the robustness of the results. However, since the service life assumed for the bridge is of eighty years, the end-of-life takes place in the distant future. Any process that is to take place so long in the future is surrounded by a deal of uncertainty since it is challenging to predict a realistic scenario. There are also limited data sources for waste treatment processes for building materials, and even so, in eighty years these processes will surely be different. It should be mentioned that several possible scenarios are possible for end-of-life, each with different environmental implications. The exclusion of the foundation works are another source of uncertainty, especially since both superstructure alternatives have different weights, the foundations required would be different.

5. Conclusions

The results from this study show that a wood design has an overall lower environmental impact than a concrete design for the studied bridge in Åstorp, Sweden. For both designs the production phase and the maintenance are the main contributors for the total environmental impact, more specifically the manufacturing of steel components and reinforcements. This result is exclusive for this case study and the assumptions made for this analysis and thus should not be generalized. However, it provides a good indication of the main sources of environmental impact for the current construction techniques applied in Sweden.

Even as the wood design involves a high degree of prefabrication; therefore double so much transport than for the concrete design, the contribution from the transports is relatively low if compared to other life cycle stages. What’s more, the environmental impact from the maintenance is comparable for both designs. This is because the main materials to be replaced in both designs are asphalt, bitumen and steel, in similar amounts.

This case study and the use of life cycle assessment contributes towards understanding the environmental impact from bridges and the role of different materials in this kind of analysis. In order to increase this knowledge, future research can study material-specific effects related to greenhouse gas emissions such as the storage of carbon dioxide in wood products or the carbonation of concrete. The inclusion of the end-of-life stage analysing different scenarios and regarding waste distribution and treatment would also be relevant.

6. Acknowledgements

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Local initiatives for motivating Danish house-owners for energy improvements

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Summary

Energy retrofitting of existing buildings is a central challenge for national and international climate policies. Although many countries have formulated national goals and policies for this, it is often on a local level and typically in a municipal context that these policies are implemented. In Denmark there are 1.1 million single family houses, representing 44% of all existing dwellings in the country. In this regard, this area is considered to have a huge energy saving potential. A growing number of municipalities have ambitions on reducing energy consumption in these buildings, and several municipalities have established initiatives for this. The paper presents the findings from a survey-based project on local initiatives to encourage Danish house-owners to save energy through energy renovation. The paper outlines actors, governance incentives and experiences related to local renovation-based policies. Based on a literature review on international research regarding home-owners motivations for energy retrofitting, the paper discusses how the municipal initiatives can promote energy renovation of detached housing. Methodologically, the research is based on interviews with municipalities and energy suppliers, whom are considered as some of the major actors to provide energy renovation among private house owners.

Keywords: Energy retrofitting, home-owners, single family houses, local initiatives, networks

1. Introduction

As for many other countries, national and international climate goals in Denmark turn our attention to the challenge of retrofitting our existing building stock. The long-term energy policy goal in Denmark is that the energy by 2050 should be carbon neutral. An important precondition for this goal is that the total energy consumption is reduced. As the energy consumption for heating in buildings consists of app. 40% of the total energy use in the country, the energy retrofitting of the existing building stock is at the core of the energy policy. It is expected that coming initiatives (as suggested by the government committee “Network for energy renovation”) will eventually lead to a reduction by 35% of the energy use in the existing building stock [2]. In this strategy, the single-family houses represent a main challenge. Technical calculations shows that in 2011 energy use in single family houses presented more than 50% of the total energy use in the building stock. In spite of national and European initiatives to regulate and promote energy retrofitting and energy savings, evaluations and studies suggests that the actual renovation activity regarding energy retrofitting is still not widespread [3], [4]. Therefore it is interesting to observe that a number of local initiatives are taking place to promote energy retrofitting of private homes, in cities, municipalities and regions [5]. The decentral initiatives are varied, both in type and content, for instance being based on municipal engagement in voluntary agreements on energy savings and CO2-reduction in the municipal territory, which not only encourages the municipalities to carry out retrofitting on their own buildings, but also to promote energy savings in the local building stock amongst private house-owners. Besides being local policies with different approaches, they are also important for the national energy supply policy, as it is generally acknowledged that a sustainable transition of the Danish energy system requires a better integration by the state level and the municipal level [6]. However, so far there has been little overview of these local initiatives carried out by municipalities, energy suppliers, financial institutes, SME's, real estate brokers, NGO's etc., and therefore little understanding of the drivers, challenges, and potentials in such initiatives. Based on these insights we are interested in how different municipalities have worked more locally with communication and facilitation of networks of owner-occupiers or with networks of actors around the home-owners. Therefore the aim of this paper is to identify and present some of the different local (and mainly municipal) initiative and policies for making house-owners energy retrofit their buildings, but not to evaluate their success, e.g. in terms of their impact on local house-owners decisions. Although the municipal strategies are not quantitatively evaluated, many of them are referred to as "best practice" in the Danish debate, and thus inspire other municipalities to similar initiatives. The research that this paper is based on [1], had the purpose to collect and systematize the knowledge – empirically as theoretically – generated in the hitherto efforts to promote energy retrofitting amongst private house owners on a local level.

2. Theory and background

In the international research there were for a long time relatively little attention on retrofitting single-family housing, however, recently there have been more focus, probably along with the renewed political interest following from the claimed high potential for energy reductions in many countries (see e.g. special issue of Building Research and Information July-August 2014 [7]). Much policy builds on the claim that it is economically feasible for the individual owner occupier to energy retrofit, however, at least within the German context this has been questioned [8]. Part of the problem is that many calculations on the potential savings built on theoretical assumptions of the energy consumption primarily relating to the theoretical energy efficiency of the buildings, whereas research show that people living in less efficient buildings use much less energy than expected [9] and the potential savings thus also will be considerably lower. The problem might be that there are many different types of homeowners and their interest and resources for doing anything with their home will thus vary accordingly [10]. Several studies have in different ways looked at how information and economy can explain energy retrofitting activities [11], [12], [13]. A general conclusion is that information campaigns just giving more information have little influence and that economy in itself cannot explain why some people energy retrofit and others do not, though in different ways the economic situation of the household and their knowledge of types of solutions can be important together with other things as a which to have a more comfortable home and to do different types of esthetical improvements [14]. This also points towards that energy retrofitting most often is not something that is done just for the sake of reducing energy consumption, but should be seen in combination with what other interest the family have in their home and the renovation of it [7]. On a European level, research suggests that home-owners involve in retrofitting projects for a number of other reasons than to save energy, and also that major challenges for energy retrofitting are the lack of skilled workforce amongst craftsmen and SME's on energy retrofitting, as well as an absence of public support schemes [3].

Following the insight that owner occupiers and their energy retrofitting activities cannot be understood in a purely individual economic perspective other researchers have pointed out how the energy retrofitting activities can be understood in a practice theoretical perspective [4],[14] where the individual is viewed as someone carrying through activities which are seen as normal in their networks, and which are supported by different structures around the owner-occupier, as e.g. professional building companies with specific knowledge [15]. It have also been argued that to promote energy retrofitting activities among owner-occupiers focus should thus not so much be on the individual households as on the local communities and networks around the home owners [16].

Across Europe, a number of climate-oriented local municipal policies and initiatives have emerged, which has been labelled as "local climate governance"-initiatives [17]. This include a shift from government to governance, where more actors are taking part in the policies, and a collaboration based on networks rather than hierarchies [18], [19], and also giving public institutions new roles where facilitation of networks are more important than traditional regulation through authority. Working with the local area and networks around the home-owners the local authorities becomes a key player, and different relevant roles for the local authorities can be identified. The municipalities can include educational activities, facilitating activities, as well as focus on their own activities and how to change them in a more sustainable direction, or they can focus on a more area-based approach working holistically with many different approaches in the same locality [20]. The municipal initiatives are often embedded in various commitments and agreements on international, national or regional scale. The committing nature of these arrangements has contributed to establishing new types of arrangements and partnerships on energy retrofitting.

3. National framework to promote energy retrofitting

A main policy approach to promote energy retrofitting has been a combination of information and economic measures, with variation between countries on the type and amount of economic measures. The Danish national energy policy has over the last decades included various arrangements and tools to motivate private house-owners to energy-retrofit their buildings. Some of these arrangements are important to understand the municipal initiatives formulated locally across the country in order to promote energy retrofitting initiatives amongst the house owners, in collaboration with other actors:

- *Building regulations:* The Danish Building Regulations has since 1961 included energy demands for all new buildings, with significant tightening of demands in 1979 and 1999. Since 2006 the building regulations has also included demands for energy efficiency when existing buildings are renovated, but so far this part has had limited effect.
- *Energy Performance Certificate:* The Energy Performance Certificate (EPC) was established in Denmark in the 1980ies. Since 2006 it has been a part of an EU-directive on the energy performance of buildings (the so-called EPBD directive). Various evaluations have looked at the

effects of the EPC-scheme, and the general impression is that the scheme only to a limited extent makes house-owners energy renovate.

- *Knowledge center for energy savings in buildings:* The “Knowledge center for energy savings in buildings”, a center under the Danish Energy Agency, was established in 2008 with the purpose to collect and communicate knowledge on practical possibilities to reduce the energy consumption in buildings. The center offers internet-based consultancy, advice and re-education of craftsmen.
- *The Energy saving agreement:* In 2009 an arrangement was made between the ministry for Climate and Energy and the energy-suppliers and –distributers on achieving energy reductions amongst end-users. The savings are documented by a “standard value catalog”, which through a simple on-line calculation defines the theoretical amount of energy saved by different types of improvements of the building or replacements of old installations with new more efficient technologies. It is important to stress, that the savings calculated by the standard value catalogue are theoretical in the sense that they are based on general technical knowledge rather than measurements in real life retrofitting. The calculations, in line with the calculations in the Energy Performance Certificate, is a measure for the energy-technical improvement of the building, measured in kWh on the basis of standard assumptions of the house, the users etc.; studies however show that there is typically a large gap between the calculated energy reductions, and the actual energy savings [21]. The suppliers can choose from different methods to achieve the energy savings amongst the end-users [22].

4. Methodology

This paper report on a broader study of how both local authorities and energy companies work with promoting energy retrofitting of owner-occupied detached housing [1], however in this paper focus is primarily on municipalities. This part of the study builds on document analysis, a telephone-based survey to municipalities and follow-up in-depth interviews with 12 municipalities selected out of the 98 municipalities in Denmark. The selection of these 12 municipalities was based on previous knowledge on how municipalities work with this field, including a pre-study among 22 municipalities where the selection included a wish to cover both the most and the least active municipalities. The present study thus purposively chose among the municipalities who were most active in motivating homeowners to energy retrofit, and also among those who were most focused on how this could be done in a way including networks and village oriented initiatives. The sample should thus not be seen as representative of all Danish municipalities, but as case-studies of frontrunners among the municipalities. Telephone interviews were carried out with an interview guide focusing on what activities the municipalities have directed towards retrofitting of owner occupied housing and who they cooperate with. Interviews were not recorded, but detailed notes were taken and case descriptions were afterwards approved by the municipalities. Furthermore a study was made among energy companies including a telephone based survey to 11 companies, a focus group interview with four companies and interviews with two other companies. Results from this material are only indirectly reported in this paper which focuses on the municipalities.

5. Findings

An overview of the initiatives directed towards house-owners by the 12 interviewed municipalities is presented in table 1. The initiatives are overall categorized in initiatives directed towards the individual house-owners (general informative approaches, outreaching approaches or initiatives in villages), initiatives directed towards craftsmen (establishing networks or re-education), energy consultancy (from the municipality or independent consultants), and collaborative initiatives (energy suppliers and financial institutions). These approaches represents a departure from former "traditional" information campaigns towards house-owners, and addresses thus some of the issues that are raised in the previously referred literature, e.g. lack of competences on energy retrofitting amongst craftsmen, lack of financial support, lack of knowledge and independent advocacy on energy retrofitting.

Table 1: Overview of initiatives to promote energy retrofitting of single-family houses in 12 Danish municipalities. By independent energy consultant is meant that the energy advisor do not have own economic interest in advising the house owner.

Initiatives	Towards citizens			Towards craftsmen		Energy consultancy	Collaborative
Municipalities	General	Outreach	Villages	Establishing networks	Re-education	Independent (I)	Energy suppliers
Frederikshavn	X	X	X	X	X	X (I)	X
Herning	X	X	X				X
Hjørring	X	X		X			X
Kolding	X	X	X	X	X	X	X
Middelfart	X	X	X	X	X	X	X
Morsø	X	X	X	X	X	X (I)	X
Skanderborg	X				X		
Sønderborg	X	X	X	X	X	X (I)	X
Guldborgssund	X	X	X	X	X	X	X
Roskilde	X	X	X	X	X	X	X
Slagelse	X	X	X	X	X	X	
Bornholm	X	X	n.a.	X	X	X	X

5.1. Energy consultancy and collaboration with energy suppliers

A core element in the municipal efforts is the use of energy consultants, especially in the outreaching efforts towards house-owners. Typically, the municipalities offer the house-owner an energy review of their house, which is either free or at a reduced price. In some municipalities the energy consultant is co-financed by the municipality and one or several local energy suppliers. As mentioned previously, the Energy saving agreement implies saving obligations for the energy suppliers and thereby creates a market among energy suppliers for energy savings at end-users. This enables the energy suppliers to pay for the energy savings reached through house-owners energy retrofitting. Therefore, some municipalities use this mechanism in collaborating with energy suppliers, so that the energy consultant is financed partly or fully by the energy supplier, and the energy savings that comes out of the energy advisors visits is attributed the energy supplier, thereby helping the company to reach their saving obligations. This is the model being used in the municipalities of Frederikshavn and Sønderborg. The energy consultant reviews the energy saving potentials of the house, and writes a report with suggestions for improvements and for financing of the various retrofitting initiatives. In ZERObolig, a public-private partnership including the municipality of Sønderborg which started in 2010, the energy consultant has visited app 1100 private homes (per summer 2013), and the secretariat estimates that this has led to 250 house-owners energy retrofitting their house, and another 250 house-owners are in the process of energy retrofitting. The estimated investment from the house-owners is a total of app 14 mill. € (100 mill. DKR). Based on the calculations in the standard value catalogue, energy reductions amounts to app 1.200 MWh. This is, as explained previously, not to be confused with the actual energy savings as experiences by the house-owner. In Frederikshavn it is estimated that the efforts have led to energy retrofitting of app. 500 houses, and theoretical energy reductions on 1.000 MWh in total. In general, the municipality states that the results mainly rely on that the energy consultants have given the house-owners personal, professional and independent advices, as well as holistic solutions, instead of single solutions.

5.2. Collaboration with local craftsmen and SME's

The re-education of local craftsmen is an important element for most municipalities' efforts, as it will give the craftsmen more competences in guiding the house-owners towards energy retrofitting, and thereby generate more renovation projects and create more local jobs. Several municipalities encourages the local craftsmen to join the energy consultant program, a 3-day course, offered by the Danish technological institute, as a part of the national initiative "Knowledge Center for Energy Renovation of Buildings" (as previously described). This will give the craftsmen the title of approved "Energy Guide". This re-education has allowed the craftsmen to perform the final approval of the energy savings, calculated through the standard value catalogue. Other municipalities offer education programs at local education centers. As an example, the municipality of Sønderborg cooperates with the local trade training center (EUC Syd) through ”Projekt ZeroByg”, which aims at promoting development and sale of energy efficient solutions and create market-based concepts aimed at export. One of the main assignments is to establish and run programs to qualify craftsmen, and to go from single solutions to system solutions, and emphasize the collaboration between different types of skills. The efforts for re-education are often supported by ambitious municipal demands on energy efficiency in new buildings and retrofitting of public buildings. In the Sønderborg-region, 65 % of the craftsmen have now completed an energy-guide education. According to the municipality, the increase in the number of housing renovation projects has further encouraged the craftsmen to take the education. As a part of the re-education, some municipalities have helped to create local networks amongst craftsmen with different skills, in order to strengthen knowledge-sharing and collaboration competences. So far, four difference networks have been established [23]. Some of the experiences are that house-owners are convinced by documentations on payback-times on different energy solutions which the craftsmen learn at the program, as well as they learn how to communicate the "success"-stories from other renovation projects.

5.3. Collaboration with other actors

Financial actors such as credit institutions and banks can play an important role as financers of the energy retrofitting. Therefore several municipalities have tried to establish collaboration with these actors, to make them aware about the benefits related to energy retrofitting, and to make house-owners aware about the possibility for energy retrofitting when they come to the bank for loans to buy or rebuild their home. The knowledge on energy retrofitting and the possible positive financial benefits related to this is generally limited amongst bank and financial personnel, and therefore various initiatives to increase their knowledge have been made. Many municipalities invite the financial institutes to the annual energy exhibitions and generally the municipalities describes the banks as being increasingly proactive and open in relation to financing energy retrofitting. There are several examples on banks and credit institutions who on own initiative establish favorable loans for energy retrofit for private home-owners, arrange courses to increase energy-knowledge for the staff, or strongly promote energy retrofitting towards local home-owners. In Sønderborg, the municipality has addressed all local banks and offered them courses on e.g.

pay-back times for different energy-retrofitting solutions, or the increased value obtained by an energy renovation of the home. In the municipality of Morsø, the four local banks have been presented for the energy review offered by the energy consultant, which has made them aware about the solutions and logic in the review. This, reportedly, has increased the banks' willingness to loan money for energy renovations of the houses. Also local real-estate dealers have been involved in some municipal strategies, although to a smaller degree, and several municipalities also emphasizes the need for a larger involvement of these actors. The rationale is that the real estate dealers can convince banks as well as house-owners about the value of a higher energy label, especially when it comes to housing trade in the outskirts of the country. With low sales prices and a poor physical condition of the houses, the costs for heating the houses might be the largest post on the budget, and therefore potentially have larger influence on the households' total economy, as compared to the larger cities, where sales-prices are much higher, and energy costs therefore relatively lower.

5.4. Initiatives towards villages

Most of the interviewed municipalities have initiatives directed towards entire villages, typically on shifting energy supply in the village from individual oil-boilers to Combined Heat and Power supply (CHP), but also in relation to promoting energy retrofitting for the house-owners. The initiatives might consist of meetings for the house-owners in the village, with participation from the municipality, energy suppliers, local craftsmen and local banks, where different types of retrofitting models are presented and promoted, included a free energy review for the house-owners. In other cases, more longstanding efforts are carried out, e.g. by denouncing the village as an "energy village". This concept has been used by a number of municipalities, implying a long-term collaboration between the village, the municipality, energy supplier etc. The character of the initiative and the selection of the villages to participate is typically a result of bottom-up initiatives where active villages contact the municipality, as most municipalities acknowledge that the village-based initiatives on energy retrofitting and change in energy supply should start with an interest and engagement among the residents. This is in line with findings from other studies, emphasizing the importance of embedding the projects locally [3]. The idea with the initiatives in the villages is that it will encourage house-owners to share knowledge, instead of informing each house-owner individually, and thereby also help strengthen local networks and social capital in the village. However, according to the municipalities, one of the challenges is that in many villages in rural areas, the houses are in a rather poor condition, meaning that renovations are rather costly, and a demolition might be a more relevant solution. Also, the residents are often DIY-oriented, meaning that they might have listened to the advices from the energy consultant, but decide to carry the energy retrofit as DIY-work, and in this case the retrofit and the savings are not registered in the standard value catalogue", and therefore not documented.

6. Discussion

6.1. Regional dimensions

As indicated earlier, the municipal initiatives reported in our case-studies are typically embedded in overall climate goals for the municipalities, as well as policies for sustainable urban development. In Sønderborg, ProjectZero, in Frederikshavn, "Energibyen", in Middelfart "Grøn Vækst", they all have ambitions municipal strategies of which the initiatives directed towards local house-owners is only one part. And the climate strategies are typically connected to overall-development plans for the municipalities, regarding job-creation, developing local competences, creating more attractive settlements, attracting residents to the region, branding the city etc. This reflects that several of the municipalities have a location outside the growth areas in Denmark. In these years, we see a strong movement from smaller to larger cities, leaving many municipalities outside the larger cities with declining population rates, an ageing population, falling housing prices etc. Some of the most ambitious municipalities on promoting retrofitting amongst local house-owners, including Sønderborg and Frederikshavn, belong to this group of municipalities. This gives certain conditions for the municipal efforts: Housing prices in these areas are generally low, compared to other parts of the country. With the low housing prices and low interest rates, the energy expenses takes up a high proportion of the monthly cost for the home-owners, making energy retrofitting attractive. On the other hand, the low housing prices and the uncertain future for peripheral regions means that it can be difficult to borrow money to finance the energy retrofitting. According to the municipalities, there are several villages and settlements where the local banks and finance institutions are not willing to lend money, as they see a large risk in continuous decreasing housing prices. Part of this reluctance from the local financial institutions is a limited understanding about the value of energy reducing initiatives. Therefore, initiatives to inform financing institutions about the value of energy retrofitting, e.g. through collaboration with the municipality, might prove valuable. This again underlines the important role that the municipality can play in order to improve the local framework for local house-owners to energy retrofit.

6.2 Energy reductions

The energy reductions defined by the standard value catalogue has proven an important element in the strategies for promoting energy retrofitting - however, this also include some challenges. As mentioned earlier, there is often a large difference between the calculated energy reductions and the actual energy savings for the house-owner. There can be many reasons for this: Primarily, the calculations only serves a technical purpose of driving the energy efficiency of the buildings, but are frequently used also as measures for the actual energy savings, but also house-owners might include many other changes in the home than just the energy-saving devices, e.g. expanding the house and adding more space, that might affect the heating bill negatively, as well as change his or her' comfort practices after the renovation. The question is whether this will affect the house-owners post-assessment of the energy retrofitting, and if that possibly will affect other house-owners decisions. Especially, the economic rationales of the energy retrofit, including the involvement from banks and financing institutions, are challenged by this issue. Also, this might affect the municipal climate strategies, as the calculated energy reductions might not be followed by a real decrease in the energy use amongst home-owners. However, the opposite argument is often heard also: That the initiatives leads to more energy retrofitting projects, as residents complete the ideas through DIY (Do It Yourself) or by using the craftsmen they normally use (and not the craftsmen with an energy certificate), which means that the energy saving projects that are actually carried through are not documented by the standard value catalogue, and reported to the authorities.

6.3 Benefits and costs of local efforts?

The direct contact to the house-owners has been a crucial element in the municipal strategies, but it is also a relatively resource-demanding strategy. Especially for the energy suppliers, the involvement in the initiatives towards the home-owners can be an unsecure business-case, and we have seen some examples on initiatives where the design of the initiatives has been changed due to this. As the regulation does not say anything about how the savings amongst end-users should be gained, the energy suppliers use very mixed strategies [22]. This includes the question if the energy suppliers at all focus on homeowners as a segment for energy reductions, as many suppliers prefers to focus on larger building owners in order to reduce transaction costs in relation to the persuasion and documentation process. As a result of this, many municipalities are increasingly focusing on initiatives in villages, hoping that local knowledge-sharing can make it up for individual visits to the house-owners. The challenges of maintaining a business-case can therefore lead to different strategies [24]: Firstly, the involved actors can remain on the track, and optimize their operations in order to maintain the arrangement as a business case (for instance by focusing on villages and more collective home-owner groups, using social media to communicate etc.), as several municipalities are considering. Secondly, as an alternative, they can accept that that the business case is less obvious, and add municipal subsidies to the arrangement (for instance to pay the salary of the energy consultant). Thirdly, they can decide to change the institutional arrangement in order to save costs, and leave it for “traditional” institutional arrangements, for instance to let craftsmen take care of the contacts with the house-owners.

7. Conclusions

The municipal strategies demonstrate a profoundly different approach to make house-owners energy retrofit compared to the hitherto efforts on a national scale. The municipal strategies seems to fill the gaps reported in research on home-owners motivations to energy retrofit, as the municipal initiatives addresses many of barriers for energy retrofitting outlined in these studies, including the direct contact to the home-owner, independent assessment of retrofitting solutions and qualified craftsmen to carry out the retrofit. An important precondition for the initiatives is that they are often embedded in ambitious climate plans and regional development strategies. Moreover, the municipal initiatives have been enabled by national and international regulation, especially the energy saving obligations amongst energy suppliers, but also national education facilities for craftsmen. Another important parameter is that the local housing market in many of these municipalities is dominated by low housing prices, where energy costs takes up a much larger proportion of the household budget, compared to the housing market in the large cities, and thereby makes energy retrofitting more attractive, but also makes it more difficult to find external financing for the housing renovation. Nevertheless, the initiatives remain fragile, partly as the business case for municipalities and energy suppliers remain uncertain due to the high costs from contacting the house-owners. Therefore, we will probably see a continuous development and adaptation of these initiatives in the future.

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Marginal costs and benefits in building energy retrofitting transaction

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Summary

Since some pioneering studies published during the late eighties, an increasing amount of research has addressed issues related to the economic and financial valuation of buildings' energy retrofitting transactions over the span of the last two decades. Nevertheless, conflicting results emerge: some hypotheses turn out to be feasible, while others do not, depending on several variables such as investment costs, energy supply costs and energy price trend. Moreover, the supposed price premium for green buildings is still unclear and ambiguous.
According to the economic theory, a way to assume decisions related to feasibility issues relies on the comparison between marginal costs and benefits. A couple of recent studies discussed about marginal costs and benefits in building energy retrofitting transactions, arguing that marginal costs are found to be steeply increasing with raising the thermal standards of buildings. Nonetheless, due to the paucity of systematic studies and consistent data, the topic deserves further investigations.
This essay aims to expose and discuss results obtained in a research conducted on public housing settlements. Analysing several energy retrofitting measures, marginal costs are found to assume a near-parabolic shape: it is, firstly, mildly decreasing and then sharply increasing. Moreover, marginal costs are compared with marginal benefits, in order to highlight feasible intervention options.

Keywords: Building energy-efficiency; marginal cost; Life cycle costing; Cost-optimum approach.

1. Introduction

Buildings are estimated to be responsible for a very high percentage of energy consumption, as they represent 32% of total final energy consumption in most IEA Countries, and human activities in the buildings cause the 40% of the primary energy consumption [1]. This suggests a growing attention within the construction sectors regarding the building's role in exploiting renewable energy and so, in reducing climate changes. The European Commission is always remarking the need of improving building energy performance, as unsatisfactory results have been achieved so far [2].
Energy use in the Italian residential sector accounted for 20% of the total final energy consumption (TFC) in 2007 but from 1990 to 2005 the same sector showed the greatest improvements in terms of energy-efficiency [3]. This reduction was mainly due to domestic efficient lamp bulbs, followed by

thermal insulation and more efficient air-conditioning systems. Energy savings for the period 2005 – 2012 amount roughly at 3.79 Mtoe/y, and more 5.16 are expected by 2016.

Approximately 62% of the edifices in Italy were built before the 1970s [4] and so before the first Italian Regulations about energy saving in the buildings were enacted. The residential building sector's contribution to the national targets is estimated at 3.67 Mtoe/y, considering the application of new standards for buildings concerning cooling and heating, thermal account, tax deduction and white certificates.

Several energy measures can be used in the buildings in order to reduce energy consumptions, in particular:

- Measures for the improvement of the energy performance of the building through the envelope (insulation, heat-insulating door and window frames, building shapes, etc.) [5];
- Use of renewables (ground source heat pumps, solar panels, photovoltaics, etc.) [6];
- Measures for reducing the heating and cooling loads (passive heating and cooling techniques, uses of bioclimatic architecture, etc.) [7];
- Actions for the improvement of indoor comfort conditions (use of mechanical ventilation combined with heat recovery, efficient use of multi-functional equipment, improvement of boilers and air-conditioning, etc.) [8];
- Use of building energy management and monitoring systems [9];
- Use of energy-efficient appliances and compact fluorescent lighting [10].

Those solutions turn out to be almost irreversible, so many efforts are spent to assess their economic feasibility in relation to the energy improvements that these measures ensure. From the perusal of the literature, it is possible to see how those proposed measures could be assessed through different approaches, which take account of financial, environmental and social factors in order to reach the most feasible solution.

Some methods which have been widely used are the Life Cycle Costing (LCC), the Discounted cash flow analysis (DCF) and the multi – criteria approaches (MCA). Kneifel [11] determines the simultaneous impacts of energy-efficient design on life-cycle costs, life-cycle carbon emissions, and energy use in an integrated building design context for commercial buildings across different climate zones. Life cycle approach has been used [12] in order to investigate the impacts of pressure duct designs on factors influencing central residential HVAC energy consumption. The study used a life cycle cost analysis to simulate the net life cycle impacts of lower pressure duct designs in dwellings. For the building retrofitting investments, LCC can be applied to estimate the overall cost of the alternatives during the life-cycle of the building and evaluate the cost-effectiveness; moreover, LCC can be used to define the optimal thickness of the insulation material in a building envelope [13] and so getting the optimum cost-effectiveness solution.

An alternative approach to the LCC is represented by Discounted Cash Flow analysis (DCF). DCF has been extensively used when valuating economic feasibility of energy-efficiency actions. One of the most popular indicators is the payback period, which, for a project, is the time in which the initial cash outflow is expected to be recovered from the cash inflows generated by the project. The simple payback period was used to assess the economic feasibility of different energy-efficiency works [14] and a discounted payback period was implemented to show the payoff of a renewable energy applied in the residential sector [15]. Furthermore, the net present value is a widely recognized indicator of economic performance and feasibility of different retrofitting actions [16, 17], in the residential and commercial sector [18, 19]. Moreover, it is used to quantify the increase of the market value of the building generated by the application of energy-efficiency measures. The net present value in the financial approach could be the measure of the energy savings and the added value due to energy performance [20].

Decision-making in retrofitting has been implemented with multi-objective optimization models (MCA) for retrofitting buildings, including a non - linear function which allows to find a different way to approach at the retrofitting options [21] and showing that an optimal solution does not exist.
Over the span of the past decade, several studies and papers introduced the cost – effective solutions in buildings retrofit. The Commission Cost-Optimality Delegated Regulation [22] establishes a comparative framework methodology to determine a cost-optimal level of minimum energy performance of buildings and building elements and a guidance document [23] on how to implement the methodology at a national level was then published in 2012.
A different cost approach has been used in marginal terms. A marginal cost approach in order to value thermal renovation of existing homes has been implemented in a series of Swiss case studies [24]: the marginal costs of energy-efficiency investments have been quantified for each increment of refurbishment's standards commencing from a baseline. The approach also introduces different scenarios, considering the lifetime of the components and allowing comparison of thermal renovation actions without using the pre-restoration energy consumption. Another method with marginal costs has been employed with the aims of finding the optimum measures of different energy-efficient elements [25] using the marginal difference between the savings and the cost of implementing those measures to renovate building fabric elements.
In this paper, we adopt an approach which includes both marginal cost and cost-optimum analysis applied to different retrofitting scenarios. The aim of the paper is to understand if the purpose of retrofitting is to achieve maximum reduction in consumption or seek a balance between investment costs and energy savings achieved with energy retrofitting measures. This essay aims to expose and discuss results obtained in a research conducted on public housing settlements, located in the metropolitan area of Milan, in the north of Italy. Moreover, different life cycle costs combined with the benefits will be used to assess the impact of some options for energy-efficient and renewable on a building over its service life.

2. Research method

In economics, marginal cost in the short run is the change in the total cost resulting from the production of one additional unit. That is the cost of producing one more unit of a good or service [26]. In the short run, marginal cost is equal to the additional amount of a variable factor that the firm should employ to increase production, multiplied by how much the company must spend in order to get an extra unit of variable factor. At each level of production and the time period being considered, marginal costs include all costs that vary with the level of production, called variable costs, whereas other costs that do not change with production are considered fixed. The marginal cost first decreases and then increases with the quantity produced, very sharply and that is due to the principle of diminishing marginal productivity.
In this paper, we analyse the marginal cost and its dynamics as it has been rarely examined for retrofitting methods, and it helps to understand how much an efficiency measure costs. Moreover, it helps to understand how much energy-efficiency can be reached through, e.g. additional insulation, defining the marginal cost of energy-efficiency, which is the difference in the investment cost due to one added step (or scenario, in our case) of retrofitting works.
The formula is:

$$Mce = \frac{Investment\ costs_n - \ Investment\ costs_{n-1}}{DEnergy_n - DEnergy_{n-1}}$$

Where the investment costs are the sum of money needed to implement the retrofitting measures, while DEnergy is the energy demand during different scenarios (n) of the building.

A second issue will be shown later regarding life cycle costs of the different scenarios. The life cycle costing (LCC) is a widely recognized method, as described in the paragraph 1.
The approach is based on the logic that economically optimal retrofitting measures minimize the sum of construction and running expenses over the building lifetime. The annual stream of costs is then discounted to present values and compared with the investment costs.

$$LCC = C_{inv} + \sum_{t=0}^{n} Ci_{inv}\left[\left(\frac{r}{q^t - 1}\right)\cdot\frac{1}{q^t}\right] + \sum_{t=0}^{n}\frac{C_{Ener}}{r-g}\left[\left(1-\frac{(1+g)^t}{(1+r)^t}\right)\right] + \sum_{t=0}^{n}\frac{C_{man}}{r-g}\left[1-\left(\frac{(1+g)^t}{(1+r)^t}\right)\right]$$

in which Cinv is the investment cost, and the sinking fund formula has been used to build up a sum of money to replace the systems after their usable life, Ce are the operating costs, Cman are the maintenance and cleaning costs, g is the growth rate, r is the discount rate and q is 1+ r. This formula will be applied with the aim of performing a cost optimal level calculation. The discussions of the results will follow the application of the models.

3. Case studies

The following three case studies described below are examples of multi–family social housings. The building # 1, constructed in 1986, develops into an L shape plant, it is a 5-storey building with two basement floors for car parking. The property is 3,212 m2. The building has reinforced concrete structure and 8 apartments per floor, of about 68 m2 each. The building is in good overall condition and has had experienced, over the years, some maintenance works. The annual energy demand is 109 kWh/m2 for heating and hot-water and 40 for electricity. The building #2 is a 4-storey construction built during the 50ies with commercial spaces on the ground floor and the three floors above are residential. There is a total of 18 apartments of about 56 m2. The building has not undergone much maintenance during its life. The building's annual energy consumption is 145 kWh/m2 for heating and hot-water and 40 for electricity. The property is 1,924 m2. The building #3 is fairly recent (90ies) and, therefore, is representative of a part of the Italian residential stock. It is a 6-storey building, with 54 apartments, which have an average size of 82 m2. The ground floor has a commercial space, and the basement houses garages. The whole building has an area of 4,914 m2. The building's annual energy consumption is 114 kWh/m2 for heating and hot-water and for 41 for electricity. The three case studies have been deeply analysed in a European research focus on existing social housing in Europe, improving measures for their energy-efficiency and using renewable energy in order to participate in the reduction of greenhouse effect gas emission [27].

Fig. 1. The three different case studies

4. Retrofit different scenarios

Thermal improvement potential of existing buildings located in the metropolitan area of Milan, and particularly in its suburban areas, has been investigated by a number of studies [28].
As far as the case study is concerned, to improve energy performance in comparison to the building as is, five retrofit scenarios were defined for each building, keeping the shape and the square meter of dwellings or commercial areas as constraints. The first three scenarios concern a better insulation of external and internal walls (1_S), of the roof and the floors in the basement (2_S), while the third scenario (3_S) focuses on the replacement of windows, by installing double-glazing with low-emission coating and thermal break frame, doors and thermostatic valves and efficient lighting system. The fourth scenario (4_S) introduces the BEMS, control system services with measures for the thermal bridges and air infiltration reductions. The last scenario (5_S) combines the previous measures with photovoltaic plants and MEV (Mechanical Extract Ventilation). Not all of these scenarios are fully applied to the three case studies: the dissimilar ages and levels of maintenance have led to different intensities of intervention in each building. So, in 1_S, for example, insulation of walls was completely added to some buildings, while in other buildings this happened just in part of it. The 5_S only combines the integration of photovoltaic panels and MEV in every building.

5. Method, assumptions and estimates

A marginal cost calculation was performed in order to understand the level of the economic impact and its intensity, in terms of cost, of the actions that make up different scenarios. The marginal cost has been calculated as explained in paragraph 2. A second issue will be shown later regarding life cycle costs of the different scenarios. The LCC has been used to support the cost-optimal analysis methodology, which has been developed by the European Commission as a tool to support decision makers about which energy-efficiency measures lead to minimum energy performance requirement achieving cost-optimal levels [29].
According to this approach, an intervention or a set of measures is efficient when the cost is lower than the sum of benefit that you will get along the expected lifespan of the measures. Future costs and savings are discounted in order to get their net present value. The cost-optimal analysis involves the identification of several scenarios, which take into account different level of energy-efficiency and, therefore, costs. The option with the smallest cost will provide the minimum level of requirements at the optimal cost. If options have the same cost, the package with the lowest energy use should normally be selected.
When applied to existing building, this approach may also consider the cost and the savings which do not have an economic value (e.g. improving internal comfort or maintenance needs) and a possible market value added to the revamped property.

5.1 Investment costs

All the scenarios previously outlined have been applied to the different buildings, which features are outlined in paragraph 3. Investment costs have been calculated through a cost estimate, a brief bill of quantities, and all costs have been considered together with design cost, security costs, materials, labour costs, equipment and scaffolding, construction services (Table 1).

5.2 Other economic inputs

In order to estimate energy consumption and savings a package has been used. The Termo here used is a software performing a steady-state simulation, allowing to calculate the primary energy need for heating and domestic hot-water production, as well as electricity consumption by means

of a procedure which relies on standards UNI TS 11300:2014, part 1 and 2 and UNI TS part 3 and 4 (based on UNI EN ISO 13790). In order to translate the estimated energy savings in monetary terms, we assume a unit energy price of 0.85 euros/kWh for gas and a unit energy price of 0.25 euros/kWh for electricity [30], an energy inflation rate of 3.5% per annum for electricity, and 3% for gas. The discount rate in this simulation is set at 5%. All the data introduced in the model are reflecting prices, costs and rates of the second semester of 2015. These data will be used in order to implement the life cycle cost of the different scenarios.
The LCC has been performed within a period of 20 years.

Table 1. Scenarios, investment costs and energy requirements for case study #1

Scenarios and energy-efficiency measures	Cost of investment Euro	Energy requirements kWh/m2 y	Energy savings kWh/m2 y	Unit cost of investment Euro/m2
0_S - Building as is	-	142.1	-	-
1_S - Building thermal coating: exterior wall insulation made by rock wool panels	89,500	102.3	39.8	32.7
2_S - Building thermal coating: insulation of floor and roof made by rock wool panels	186,600	73.6	68.5	68.3
3_S - Windows replacement: double glazing with low-emission coating and thermal break frame, thermostatic valves	207,500	63.3	78.8	76.0
4_S - Introduction of BEMS, control system services, thermal bridges reductions	345,700	54.8	85.3	126.6
5_S - New ventilation system	645,700	43.7	98.4	336.5

Table 2. Scenarios, investment costs and energy requirements for case study #2

Scenarios and energy-efficiency measures	Cost of investment Euro	Energy requirements kWh/m2 y	Energy savings kWh/m2 y	Unit cost of investment Euro/m2
0_S - Building as is	-	184.6	-	-
1_S - Building thermal coating: exterior wall insulation made by rock wool panels	26,700	92.3	92.3	24.92
2_S - Building thermal coating: insulation of floor and roof made by rock wool panels	35,900	85.6	99.0	33.4
3_S - Windows replacement: double glazing with low-emission coating and thermal break frame, thermostatic valves	100,800	62.2	122.2	94.0
4_S - Introduction of BEMS, control system services, thermal bridges reductions	189,400	51.3	133.3	176.6
5_S - New ventilation system	305,750	45.0	139.6	285.2

Table 3. Scenarios, investment costs and energy requirements for case study #3

Scenarios and energy-efficiency measures	Cost of investment Euro	Energy requirements kWh/m2 y	Energy savings kWh/m2 y	Unit cost of investment Euro/m2
0_S - Building as is	-	154.6	-	-
1_S - Building thermal coating: exterior wall insulation made by rock wool panels	239,000	85.7	68.9	57.33
2_S - Building thermal coating: insulation of floor and roof made by rock wool panels	390,800	57.5	97.1	93.5
3_S - Windows replacement: double glazing with low-emission coating and thermal break frame, thermostatic valves	465,300	51.8	122.2	111.4
4_S - Introduction of BEMS, control system services, thermal bridges reductions	799,300	43.4	111.2	191.3
5_S - New ventilation system	1,126,000	36.9	117.7	269.5

6. Results and discussion

For each scenario, marginal costs and LCCs have been calculated, which results are displayed in Fig. 2 and 3. The marginal costs in Fig. 2 show the traditional shape usually depicted in economic theory: in the first part, the cost increases very slowly or with a mild decrease in value, and then it shows a step-wise increase due to the principle of diminishing marginal productivity.

In 1_S, for all case studies, albeit with limited capital, the efficient energy level fully compensates the investments. In contrast, in 4_S or 5_S, to get even a small improvement of the building's energy performance, it is necessary to invest considerable sums of money. The nonlinear relationship between energy retrofitting costs and higher energy standards is well-known in the construction market: an increase of, let's say, 10% of the costs of investment do not match a decrease in energy consumption of equal proportion.

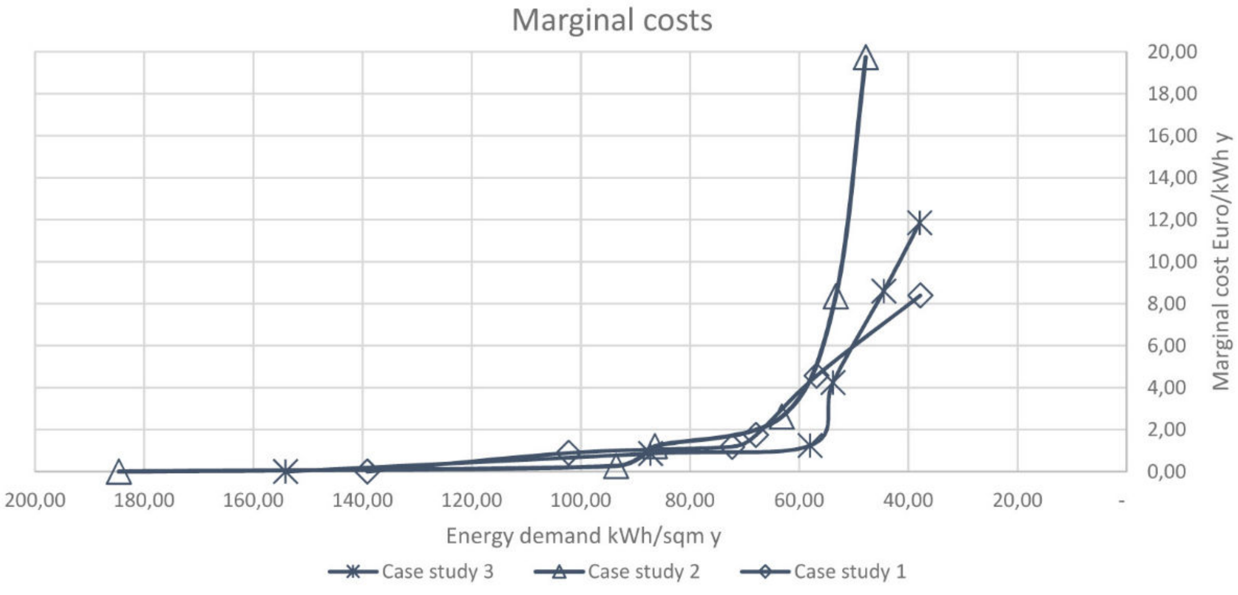

Fig. 2 Marginal costs for multiple family houses

The marginal cost curves of the first and the third building, which are relatively modern properties, do not increase as sharply as does that of the second building in 4_S and 5_S. In practice, the marginal increase in investment costs leads to an increase, albeit less effective compared to the first scenarios, of achievable energy savings. The building #2, which is a 50's construction of a very poor maintenance level, shows a curve that despite substantial measures of energy retrofits, increases very rapidly, and it is almost vertical in its last part: subsequent works do not improve building energy standard. Old buildings in poor maintenance conditions, even if actions include the combination of efficient energy measures, the use of renewable energy and technologies for the control of energy consumption, do not get proportional improvements in energy performance, and surely cannot reach the standards of passive houses. The decision makers or the investors should find the optimal scenario, and that point in the curves of marginal costs is represented by the one preceding the rapid growth of cost. In case study #2 and #3, this point corresponds to the package of measures that characterize 3_S and 4_S, while in the building #1 costs increase rapidly after 2_S.

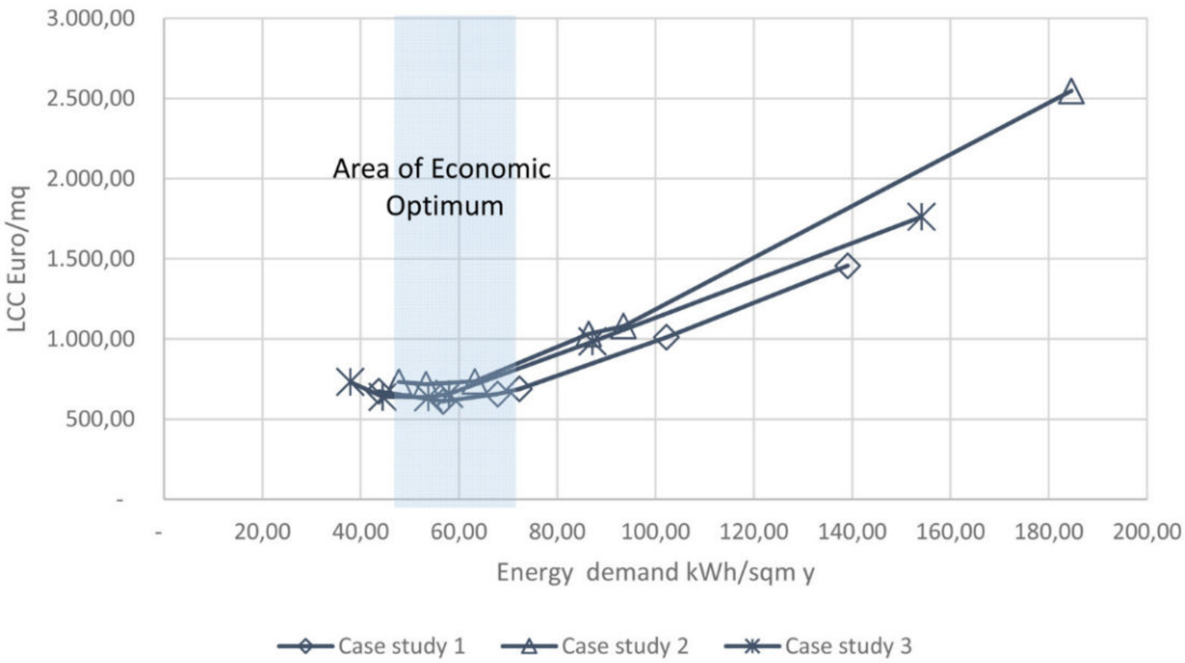

Fig. 3 Cost-optimum options

In order to detect the optimal scenario, in addition to an analysis which includes only the initial costs, a cost–optimal approach has been adopted, which includes the calculation of the life cycle costs for a period of 20 years. The results of the analysis are represented in Fig. 3. The concepts of cost efficiency and cost–optimality are related but different as a cost–effective action is when the cost of its implementation is lower than the present value of the expected benefits. The cost-optimal result is the retrofit action that minimizes the total costs. In Fig. 3 the range of economic optimum, for all case studies, is obtained when the overall cost gets its minimum at the level of the energy requirements of approximately 55 kWh/m2 years. Such energy consumption values are very similar in all case studies, although in the building #2 and #3 these could be reached through the actions of 4_S, while in building #3 those measures concern 5_S. The life cycle costs increase when energy demand is around 30-40 kWh/m2 year due to the high investment costs. The analysis of the two models does not fit together: however, it should be stressed that the first model based on marginal costs does not consider the costs that will be incurred in the future. The LCC approach considers the whole life cycle of the property, or as in this case, the costs that occur in a given period of analysis.

7. Conclusions

The analysis performed suggests that methods as Marginal costs and Life Cycle Cost might help to find the best scenario or combination of measures to improve the energy performance of the building. In existing buildings, the cost-optimal solution is not necessarily the one that leads to the lowest energy consumption. Often these actions have a high investment cost, and the marginal cost grows very quickly, not having, as a counterpart, equal reduction in energy consumption. And moreover, it is difficult to justify renovation to the highest standards if the costs rise exponentially while the amount of energy saved grows slightly. Sometimes it is technically not possible to reach that standard in existing buildings as the thermal insulations, for example, could not fit the physical form of the building, or the shape of the roof, or the terrace. The roof overhanging a wall could be too small to accommodate layers of insulation so a complete substitution of the roof could be required, with obvious additional costs [31]. Another issue arises when investment costs over – exceed the owner/investor budget constraints or he/she is not willing to pay that sum of money today and cash the benefits in the future. The payback period could be simply too long, so there is not financial profitability in investing in energy-efficient measures. The scenario with the higher energy saving, for economic and technical reasons, might not be the best option.
Future research could analyse the market value of those buildings which have been renovated, in terms of possible value recouped in comparison to the investment costs to value the green premium. This analysis could help to find different options of economic optimum solutions, which could diverge from the ones identified here.

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MODELLING APPROACH FOR THE THERMAL RESPONSE OF A RESIDENTIAL BUILDING EQUIPPED WITH A CHP UNIT IN AN URBAN AREA

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Summary

The work presented in this paper was carried out within a research project in the city of Bottrop, Germany, where 100 combined heat and power (CHP) systems were installed in existing residential buildings. In order to analyse the dynamic thermal behaviour of a residential building including its CHP units, Modelica was used to model the behaviour of both the buildings and CHP units. These buildings differ with regards to construction type, insulation standards and age. Based on previous modelling and verification of a multi-zone model for an existing technology demonstration centre at Gas- und Wärme-Institut Essen e. V., this paper shows the physical and mathematical simplification by using an alternative one-zone model in order to reduce the numerical effort. Finally a validation of this approach is presented by comparing simulation and experimental results of one building for three separate periods of time, including heating, swing and non-heating periods. Additionally, a simulation covering an entire year is shown, based on Test Reference Year (TRY) weather data as boundary conditions.

Keywords: Modelica; thermal zone simulation; urban simulation; CHP

1. Introduction

Since the beginning of the industrial revolution mankind has been affecting the world climate. The massive emission of carbon dioxide (CO_2) and other environment harmful gases increase the greenhouse effect and lead to variations in global temperatures. Arguably, result in drastic consequences the climate on our planet. To reduce the impact of global warming to a manageable level, the range of carbon dioxide in the atmosphere has to be limited [1]. Yet a big part of total consumption of energy in our lives is consumed through buildings. For instance about 26.1% of the final energy consumption (heat and electricity) in Germany was consumed in 2013 by the residential sector and 40% in the European Union. Therefore it is fundamental to enhance their energy performance, for example by supporting the improvement of the walls insulation, the installation of efficient windows or the substitution of old boilers with CHP units. The cogeneration technologies provide an efficient and clean approach for generating (on-site) electrical power and useful thermal energy from a single fuel source. To study methods for increasing performance in the buildings, it is necessary applied these in simulation tools. These tools allow valuing the afterward energy demand and identifying the parameters which affect the consumption, in order to shrink the energy consumption. To this purpose, many researchers [2-7] have proposed different modelling investigations, specifically for quarter simulations, aiming at supporting the energy efficient design of different kind of buildings.

At Gas- und Wärme-Institut Essen e.V. (GWI) a complex model of an individual house (a technology demonstration centre on GWI) with its various heating appliances were presented within a research project [8]. Moreover, a dynamic simulation tool with Modelica was presented [9] with two libraries to enable to study the impact of different parameters, such as local energy solution, on the energy consumption. Furthermore, simplified models were developed during the research project at GWI [10]. The action was carried out on 100 buildings in various places in a district of urban area in Germany. Since the aim is to simulate this task for a large number of buildings, it is decided to explore simplified methods for simulating thermal energy flows in the buildings. Another reason was that in the complex model of the house, there are a significant number of parameters, and many of them are related to geometrical and thermal properties of the materials, which are not usually provided by the building owner or manufacturer of the building components. However it is desirable to ensure that we have compatibility between the available data, the approach for simplification and a fast but accurate simulation. Due to this motives and based on the component of the two libraries and the complex model mentioned before, model simplification techniques were applied on the complex modelled house. In this project the non-building consumers and urban effect (i.e. energy consuming in streets and the effect of impact wind from other neighbours building) were not considered in the energy balance calculations.

2. Methodology and Modelling Approach

2.1 Methodology

The employed methodology starts first with the reduction of the number of buildings in order to provide a manageable sample which represents the districts reasonably well. As a result, the number of the simulated buildings reduced to 10 “reference buildings”. The selection of reference buildings is based on the location of buildings, year of construction, number of occupants, heating technology and energy heat load. Accordingly, inspections were carried out by visiting each reference building to measure the volume of each heated room for each reference building. Likewise, the surface areas of the outer walls, windows and doors for heat transfer calculations should be specified. Thereafter the obtained data were implemented in each building model. Similarly, the radiator types and geometries were compiled and used as boundary conditions in the model approach to enable calculating the total thermal power supplied by all radiators in each building, based on reference data. The next step was to simplify the complex house model by reducing the multi-zone model into a one-zone model. A single heating zone is taken into account considering an effective thermal zone in which all internal inner masses are lumped together, i.e. summing up all inner volumes (air) into a building with single volume. For example, all zones the first and second floor in figure 1 were modelled as one zone. Unheated zones were assumed to have a constant temperature during the simulation time scale. The other components were characterised to be lumped into one area on each side of the building block model (north, east, west, south, roof, and ground). In addition, the whole air volume inside building was modelled to balance the whole thermal energy. The mentioned building components where physically modelled and parameterised based on the real chosen building.

The building model takes into account the following physical processes:

- Transient heat conduction through the system.
- Heat convection between the outside air and outside facing surfaces using a variable heat transfer coefficient as a function of wind speed.
- Infrared heat transfer inside and from ambient environment (opaque or transparent)
- Balance equations for energy to determine the air temperature in the considered computational domain.

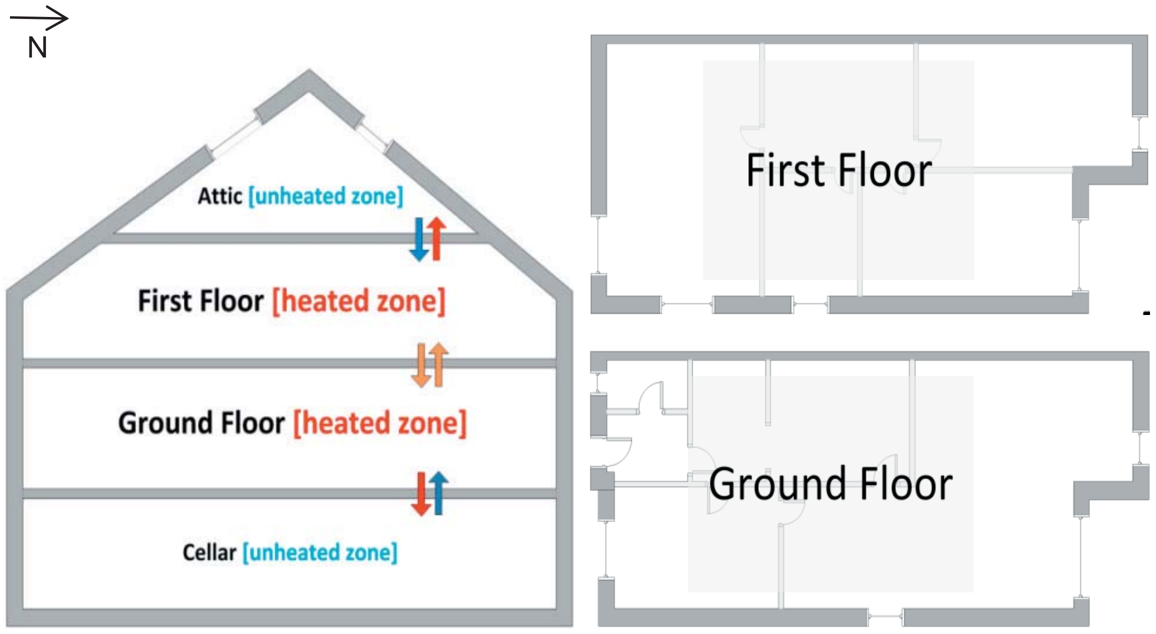


Figure 1: Left: A schematic of one of the considered reference buildings. Right: Heated zones in the modelled building

2.2 Modelling

A sampling approach using a small number of representative building models appears to be well-suited to handle large building populations with a manageable numerical effort.
In order to avoid uncertainties, relatively simple building models for two types of buildings were developed for this investigation. The thermal zone volume is determined through the inside surface of the whole building. The determination of the outer surface areas were based on external dimensions, which is important, for example, for the heat transfer calculation (U-values etc.). Furthermore, in the last decades the technology of heat supply has been developed and became more energy efficient. It becomes so crucial so that the year of installation of the heat supply system can be considered as a characteristic for the energy efficiency of the whole building.

2.2.1 Building

A good description of the characteristics of a building is very important, since there are several parameters that influence the energy performance. Ten reference buildings were modelled as either Single Family House/Terraced Houses or Multi-Family Houses. Single und terraced house models are similarly modelled but with different parameters. In this paper a case study of terraced family house is discussed. The house built in 1904 and completely refurbished in 1988 is presented. The geometrical and thermo-physical properties are summarised in Table 1 and table 2.

Table 1: Used geometrical characteristics of simplified thermal building.

Area/Direction	North	East	South	West
Wall [m^2]	29.8	67.4	29.8	67.4
Window [m^2]	8	X	1.4	4.3
Door [m^2]	X	X	2.4	X

Table 2: Selected U-value of the building components.

Transmittance	U_{Dach}	U_{Wall}	U_{Window}	U_{Ground}	U_{Door}
W m^{-2} K^{-1}	0.4	0.6	3.5	0.51	3.00

In general the total net heat demand in the building is calculated through the difference between heat losses and heat gains in a building, see equation (1) and table 3. The temperature difference between an ambient and a room, force the heat to flow from one domain to another one. The equations below describe the used heat transfer's equations in the building model.

$$Q_{total} = \underbrace{[Q_{transmission\ losses} + Q_{air\ exchange\ losses}]}_{\text{Heat Losses}} - \underbrace{[Q_{solar\ gains} + Q_{internal\ gains}]}_{\text{Heat Gains}} \quad (1)$$

Heat losses through transmission $Q_{transmission\ losses}$ were calculated in Modelica as below:

Table 3: Used Heat transfer [11], [12] equation in models and in Modelica

Heat conduction	$Q_{Cond} = \lambda*A*(\Theta_a - \Theta_i)/d$ λ: Thermal conductivity A: Area Θ_i: Inside temperature Θ_a: Outside temperature d: Thickness	equation Therm1.Q_flow = lambda*A/d*(Therm1.T - Therm2.T);
Heat convection at exterior wall	$Q_{Conv} = \alpha*A*(\Theta_a - \Theta_i)$ α = 4 + 4*v A: Heat transfer coefficient v: wind velocity	equation alpha = (4 + 4*WindSpeedPort); Therm1.Q_flow = alpha*A*(Therm1.T - Therm2.T);
Heat radiation orthogonal	$Q_{R12} = \varphi_{12}*\varepsilon_1*\varepsilon_2*\sigma*A$ φ_{12}: Emission value of object (0..1) σ: Stefan-Boltzmann-constant. A: Object's surface area where radiation takes place	equation Therm1.Q_flow = F12*eps1*eps2*A1*Modelica.Constants.sigma*((Modelica.SIunits.(Therm1.T))^4 (Modelica.SIunits.(Therm2.T))^4);
Heat losses through air exchanges	$Q_{ax} = V*\rho*c_p\ (\Theta a - \Theta i)$ V: Volume of the room ρ: Air density c_p: Specific heat capacity of air	equation Therm1.Q_flow = InPort1*V*c*rho*(Therm1.T -Therm2.T)/3600;
Heat gains through solar radiations	$Q_s = I*A*Coeff$ I: Radiant Energy Fluence Rate	equation Therm1.Q_flow = -ic_total_rad1.I*A*coeff;

Finally, the internal heat sources were determined by defining a timetable and the type of activity [7], based on time dependent data tables for the heat production of persons and electrical devices. Simulations were carried out both with and without these heat sources.

Figure 2Figure visualizes the model of terraced house as one-zone model with its radiator system.

The required internal temperature, while night setback is switched off, is 21 °C with a tolerance of ± 2 °C. During an activated night sellback mode the internal temperature is 14 °C with the same tolerance.

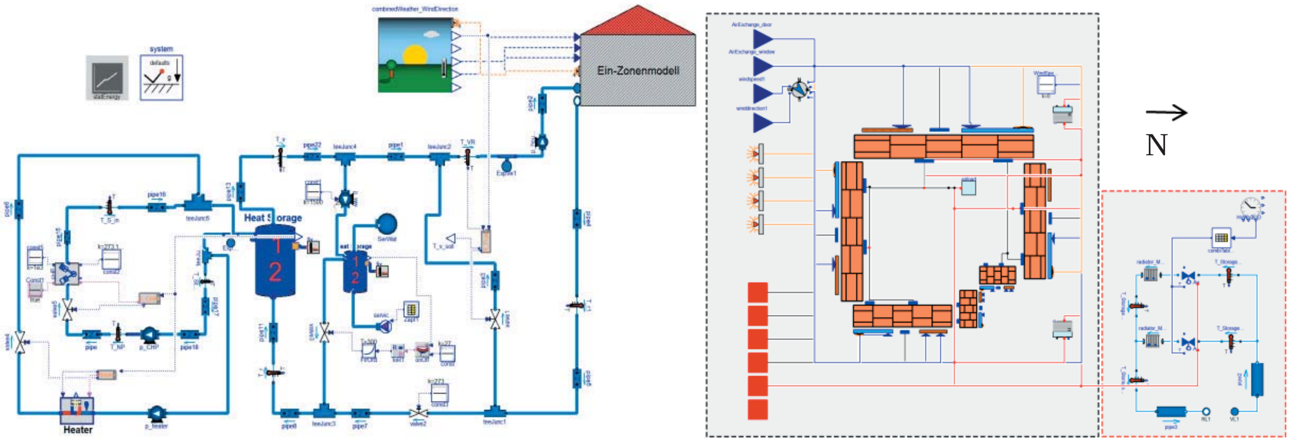


Figure 2: Left: Single zone model with the hydraulic system in Modelica. Right: A one-zone model inclusive radiator in Modelica.

2.2.2 Climatic data

In this case study, the outside temperatures in each building were measured. The solar radiation and other meteorological data were not recorded. To decide which climatic data would be used for the simulation, a comparison between the weather data provided by Germany's National Meteorological Service (DWD) [14] and the locally measures ones were done. Figure 3 shows that DWD data are close enough for representing climatic data for the considered building simulation.

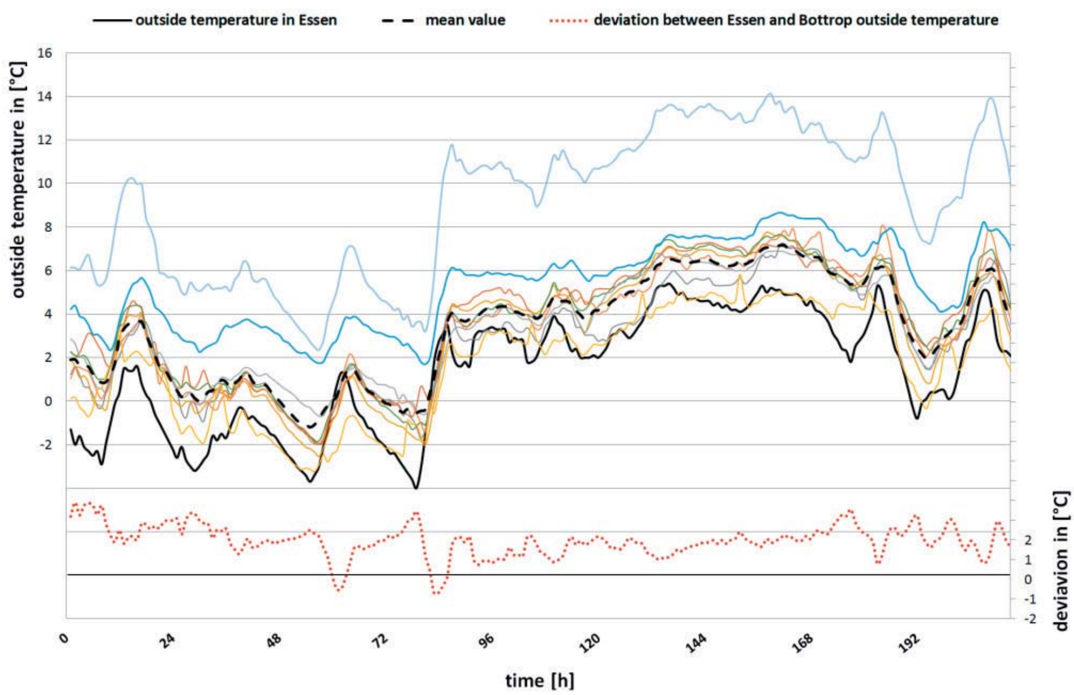


Figure 3: Comparison of measured (Bottrop) and DWD (Essen) outside temperatures for the cold period during year 2015.

Where the coloured lines show the local measured values in each reference buildings (Bottrop), black dashes show the mean value of the measures ones, the black line the show DWD Essen values and red dots represent the deviation between the mean values from Bottrop and Essen values. The data sets include hourly values of outside solar radiation and meteorological elements for a two years period.

2.2.3 Supply system

The subsystem (CHP with an auxiliary boiler) model is the energy central supplier for covering heating, warm-water demand and a part of electrical demand in each reference building. The Building and its hydraulic are implemented separately in sub-model components. Nevertheless, the Simulation of each reference building takes place separately. The equations for energy balance calculations were used as described in [15]. The model of heating system, energy provider, is parameterized according to the manufacturer's parameters.

2.3 Model validation

For the validation of the building and the heating system models, it was necessary to compare the results of heat demand at winter, swing and summer periods. These periods are selected according to the outside temperature as shown in table 4, in which the heat demand of the building is mostly affected.

Table 4: The selected boundaries for the three periods; outside temperature ranges and time intervals

Period	Outside temperature [°C]	Validation period intervals	Yearly period intervals
Winter	T ≤ 10	30.Jan. - 09.Feb.	01.Jan. - 30.Apr. & 01.Nov. - 31.Dec.
Swing	15 ≥ T ≥ 5	30.May - 10.Jun.	01 - 15.May & 01.Sep. - 31.Oct
Summer	T ≥ 10	04.Jul. - 14.Jul.	16.May - 31.Aug.

The selected parameters for the validation are presented in Figure 4 (a-d). Figure 4 (a) represents a comparison between measurements and simulations for the accumulative electrical power generated by CHP, heat consumed by building and total fuel consumed by heating system in winter, which shows a good agreement between both characteristics and values. The simulated and measured values for generated electrical power by CHP unit are 143 kWh and 153 kWh, for heat demand are 710 kWh and 760 kWh and for fuel consumption are 111 m^3 and 125 m^3. The small nonconformities mentioned above are in the accepted measurement error range. This is because of the implemented user behaviour for warm water consumption (VDI 4655) and the assumed ventilation profile (windows and doors) in the building model. A comparison between the measured and simulated values of both electrical power generated by CHP and the heat consumed by building at each step point are shown in figure 4 (b-c). These are significant to compare the dynamic response at each simulated step (5 minutes), which show also very good conformities with the measured one. The 5 minutes step is the interval of the measurements readouts. Furthermore, the simulated temperatures inside the building reach the pre-defined set values as shown in Figure 4 (d). The set values are the reference inside temperatures during day and night time. The small disparities occur mainly while the heating system is starting-up or down. The disparities in the temperatures are still in the allowed range (5 K).

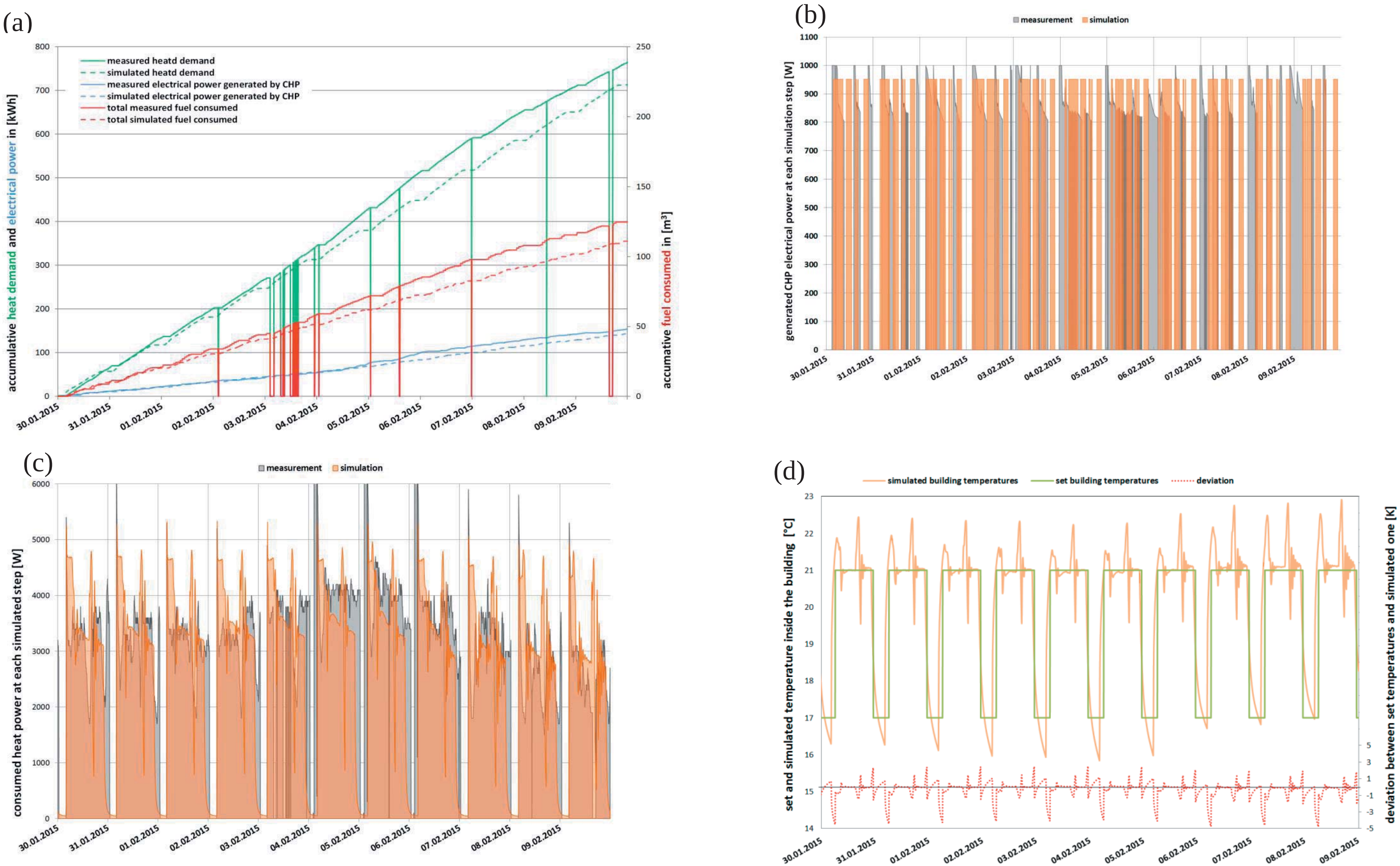
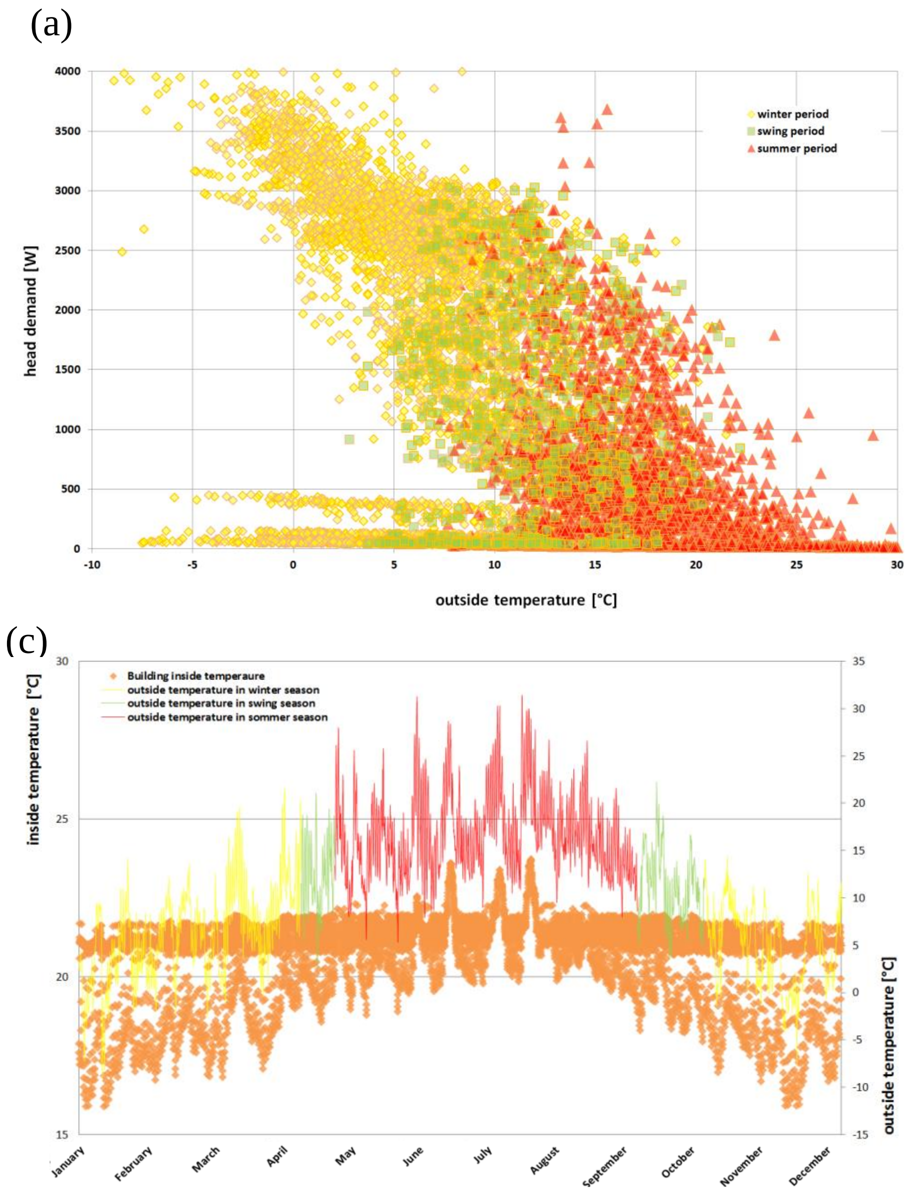


Figure 4: Comparison between measurement and simulation data in winter season for: (a) accumulative electrical power generated by CHP, heat consumed and total fuel consumed by heating system (b) electrical power generated by CHP at each measurement/simulation step and (c) heat consumed by building at each measurement/simulation step. (d) represent the set and simulated inside temperature in the building.



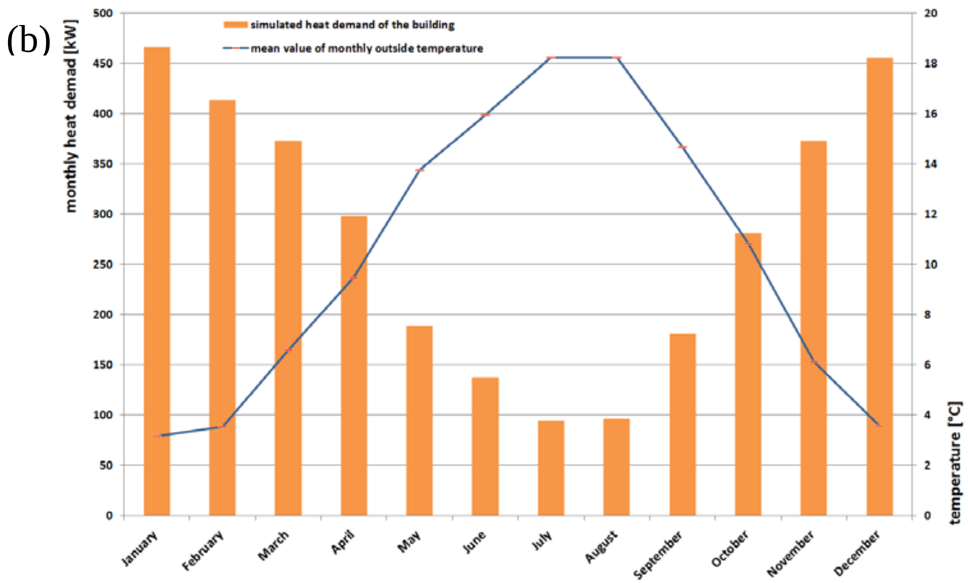


Figure 5: (a) Simulated heat demand of the building over one year, (b) monthly heat demand and average outside temperatures, (c) building inside temperatures and outside temperatures for each period

The validation procedures for swing and summer periods are similar to the winter period. The accumulative profiles (electrical power generated by CHP, heat consumed by building and total fuel consumed by heating system) and the instant values (electrical power generated by CHP and the heat consumed by building at each measured/simulated step) show also a good agreement between the measurements and the simulations. The complete procedure for all periods is presented in the final report of the research project [10].

Additionally TRY weather data was used to provide input for the simulation over an entire year to describe the dynamic behaviour of heat demand of the above validated building model. For this simulation, three periods were selected to distinguish the results easily as shown in table 4 and figure 5.

Figure 5 (a) shows the heat demand versus outside temperature. The simulated points distribute in the expected manner. This is specially recognised during different colours. Additionally part (b) in figure 5 represent the relationship between the heat demand and the outside temperature. The same behaviour indicated in figure 5 (c) in which inside temperature and outside temperatures were displayed.

In total, the accuracy and the consumed simulation time between both the multi zone [8] and a single zone model were issued. This is significant to get more obvious about the whole time needed to simulate 10 reference building. Table 5 demonstrate the accuracy and the simulation duration of mentioned models during the three periods and the yearly simulation. These results submit that the simplifications and reduction in the model induce only a small error percentage in the 10 days simulation time periods. Nevertheless, a big saving in simulation time efforts was occurred. The values are accurate enough to reproduce the dynamics of the detailed model for district simulations.

Table 5: Percentage reduction of accuracy and simulation time due to single zone model

	Winter	Swing	Summer	Yearly period
Accuracy	10	6	12	16
Simulation time	45	45	45	68

3. Conclusions

The work presented in this paper aims to develop numerically efficient yet accurate building models suitable for energy balance simulations of large numbers of buildings.

While the verified multi-zone model is well-suited for detailed simulations of single buildings, the simplified model presented here was developed for the simulation of entire city districts. The comparison between empirical and simulated results for three periods shows that the simplifications and reduction of the model cause only a small percentage of error. On the Contrary, the reduction’s percentage of the simulation time efforts is rather big. 45% time was saved over three periods for the validation and 68% was saved during the yearly simulation.

The simulation of the thermal behaviour of the building over the span of a year agrees well with theoretical expectations. This demonstrates that the models both for single components and the entire system are now available and can now be used to numerically investigate different scenarios.

4. Acknowledgements

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Monitoring of Energy-Saving Processes in Residential Building Stocks

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Summary

The EU and its member states have formulated ambitious CO_2 reductions and energy efficiency goals for the next decades. The potential of the housing stock to contribute to these savings is considered to be significant. But setting up targets and milestones is not enough – they have to be met in practice. To check if strategies, objectives and activities undertaken are appropriate and contribute sufficiently to the formulated aims, a well thought out evaluation and monitoring framework is necessary.

In the frame of the EU project EPISCOPE case studies on either national, regional or local level were undertaken in 16 countries to map existing housing stocks, and show prospective energy and CO_2 reductions by means of scenario calculations. Apart from a discussion on applicable indicators, special attention was paid to the identification and discussion of available data sources including information about the considered building stocks as well as data quality, data gaps and possibilities to improve data collection.

It can be summarised that the data situation of European residential building stocks is in general unsatisfactory. As a consequence, there are wide information gaps concerning the actual state as well as the trends of building thermal insulation and efficient / renewable heating systems.

Therefore, more awareness needs to be created concerning the importance of setting up a more robust information base, because reliable and up-to-date data are needed to form the foundation for the discussion on climate protection strategies in building stocks.

Keywords: Residential Building Stocks, Monitoring, Energy Savings, Data Availability, Data Quality

1. Introduction

Climate change has long been recognised to be a challenge, for which coherent actions are needed at national, European and global level. In order to keep climate change below 2°C, the European Council reconfirmed in February 2011 the EU objective of reducing greenhouse gas emissions (GHG) by 80-95 % by 2050 compared to 1990 [1], in the context of necessary reductions according to the Intergovernmental Panel on Climate Change by developed countries as a group [2]. In its "Roadmap for moving to a competitive low carbon economy in 2050" the European Commission outlines milestones which would show whether the EU is on course for reaching this target [3]. The roadmap also shows the scope of possible GHG reductions for different sectors according to their technological and economic potential. Above average contributions in the medium and long term are expected to be achieved by the residential and service sectors (88 % - 91 % decreases of GHG emissions in 2050, compared to 1990 levels), "due to significant reductions in required heating from improved insulation and greater use of electricity and renewables for building heating as well more energy efficient appliances." [4]

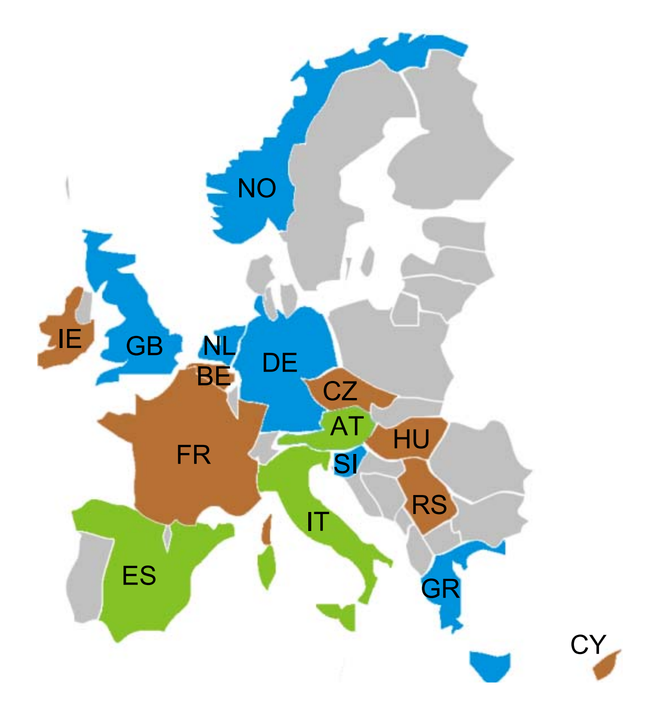
It is the responsibility of the EU Member States to define appropriate strategies and implement national policies to support the European targets, and many countries have set up national frameworks to tackle climate change, like e. g. the UK with its Climate Change Act 2008 [5] or Germany with its Energy Concept 2010 [6], in which also special milestones and targets for existing and new buildings are defined, aiming for the building stock to be climate neutral by 2050.

But setting up targets and milestones is not enough – they have to be met in practice. To check if strategies, objectives and activities undertaken are appropriate and contribute sufficiently to the formulated aims, a well thought out evaluation and monitoring framework is necessary.

The Institute for Housing and Environment has been dealing with such approaches for residential building stocks in Germany on different scales by conducting sample surveys representative for the German residential building stock as a whole [7], and the share of residential buildings subsidised by the KfW Bank [8], as well as monitoring concepts for the national residential building stock [9], the residential building stock in the federal state of Hessen [10], and a district in the city Mainz [11]. Applicable indicators and approaches for building stock models were furthermore discussed in the framework of the European projects DATAMINE (2006-2009) [12] and TABULA (2009-2012) [13]. Building up on this previous work and similar national experiences in several European countries recommendations for monitoring processes in residential building stocks on national, regional or local scale were elaborated during the European project EPISCOPE (2013-2016), co-funded by the Intelligent Energy Europe Programme of the European Union. In the following, an overview of these results from the EPISCOPE project is presented.

2. The EPISCOPE approach in brief

Case studies on either national, regional or local level were undertaken in 16 countries (see Fig. 1) to map existing housing stocks, and show prospective energy and CO_2 reductions by means of scenario calculations. The respective results are documented in two Synthesis Reports [14] and [15].



Local Case Studies

BE – Belgium:
Housing block in the Sint-Amandsberg district in the city of Ghent

CY – Cyprus:
Housing stock of the Cyprus Land Development Corporation CLDC

CZ – Czech Republic:
Municipal housing stock in the city of Havířov

FR – France:
Social housing stock of OPH Montreuillois in the city of Montreuil

HU – Hungary: City of Budaörs

IE – Ireland:
Municipal housing stock on the Northside of Dublin City

RS – Serbia: Municipality of Vršac

SI – Slovenia: Municipality Kočevje

National Case Studies

DE - Germany, GB - England, GR - Greece
NL – The Netherlands (national non-profit housing stock), NO - Norway, SI - Slovenia

Regional Case Studies

AT – Austria: Salzburg
ES – Spain: Comunidad Valenciana
IT – Italy: Piedmont Region

Fig. 1 Countries and case studies on residential building stocks, covered in the framework of the EPISCOPE project

Apart from a discussion on applicable indicators [16] (see section 2.2), special attention was paid to the identification and discussion of available data sources including information about the considered building stocks as well as data quality, data gaps (see section 3) and possibilities to improve data collection (see section 4) [17]. At first glance, the question of basic data might appear secondary and more a matter of expert discussions and footnotes. But the project team considers it to be a key question, because reliable and up-to-date information is needed as a basis to control the success of already implemented measures on the one hand and the further development of appropriate strategies on the other hand.

2.1 The role of monitoring in climate protection strategies

As shown in Fig. 2, monitoring data form a basis for building stock models (often based on building typologies) and scenario analyses. Structural data about the existing state – e. g. the current share of wall areas already insulated – deliver the starting point of building stock modelling, while information about recent dynamics – e. g. the share of wall areas insulated per year – are necessary inputs for trend analysis. Observation of changes over time therefore not only shows if specific milestones have been reached in the past and corrective actions are needed, they also deliver important information for the further development of strategies and policy instruments. The effect of measures undertaken can in turn only be determined by means of renewed data collection and analysis. To effectively monitor a climate protection strategy this process needs to be run through several times. As a consequence, a continuous monitoring procedure to provide and analyse up-to-date information on a regular basis needs to be established.

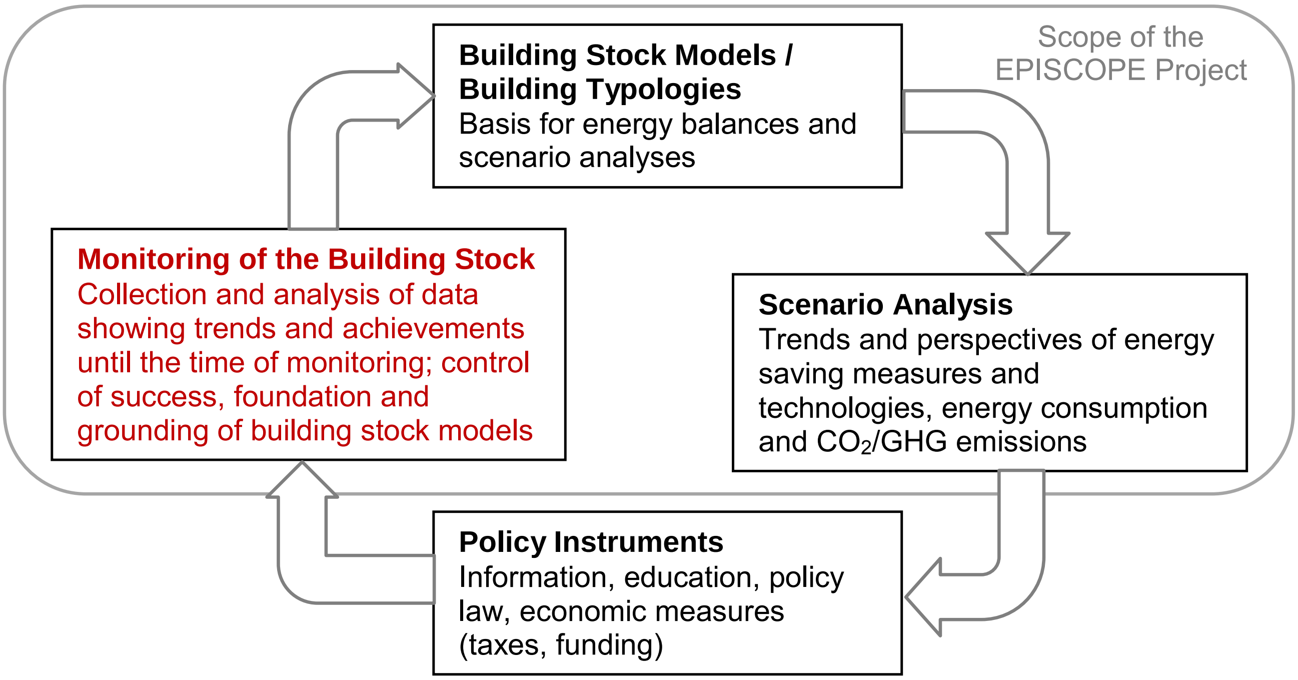


Fig. 2 Procedure of implementing and monitoring climate protection strategies in building stocks in schematic form

2.2 Requirements for monitoring indicators

To effectively monitor energy saving processes in building stocks, the identification and definition of appropriate indicators is essential. The indicator scheme needs to be suitable to map the state of the building stock at a particular point in time as well as to understand the dynamics of the development over time. Furthermore, it needs to be possible to collect the respective data by means of feasible, reliable methods as e. g. representative surveys.

To set up building stock models with regards to energy balance calculations, basic and structural data are needed on the building stock considered:

- Basic data, e. g. number of buildings, number of dwellings; m² reference area, age bands;
- Quantitative information on thermal protection / building insulation, e. g. shares of insulated building components;
- Information on the depth of refurbishment measures, e. g. thickness of insulation, U-values, classification of insulation levels;
- Information on supply systems, e. g. grade of centralisation, main energy carrier, type of heat generation, solar thermal systems, PV systems, main systems of hot water generation;
- Energy consumption by fuel to enable a calibration of calculated results for the respective years considered.

To be able to distinguish between specific subsets of a building stock, these data are required for the respective clusters, grouped e. g. by building size (single/multi-family home) and/or specific age bands.

When analysing past and possible future developments, it is furthermore necessary to distinguish between reliable "scientifically measured" monitoring indicators and scenario indicators, which are to a more or less extent based on assumptions. Fig. 3 illustrates a complete indicator set, describing the building stock in its actual state at a specific point in time and in its future conditions. Monitoring indicators are supposed to directly reflect the monitoring results, they should not depend on additional (more or less unproved) assumptions. State indicators describe the condition of the building stock in a certain year, and provide information about the current status of energy efficiency. Trend indicators are related to the actual dynamics, and provide information about the current velocity of movement towards better energy efficiency and climate protection. These structural data are basic input data for scenario analyses and thus also form the basis for related scenario indicators. Whereas the indicator scheme in general refers to quite detailed information, results of overriding importance should be shown as summary indicators also understandable for non-experts.

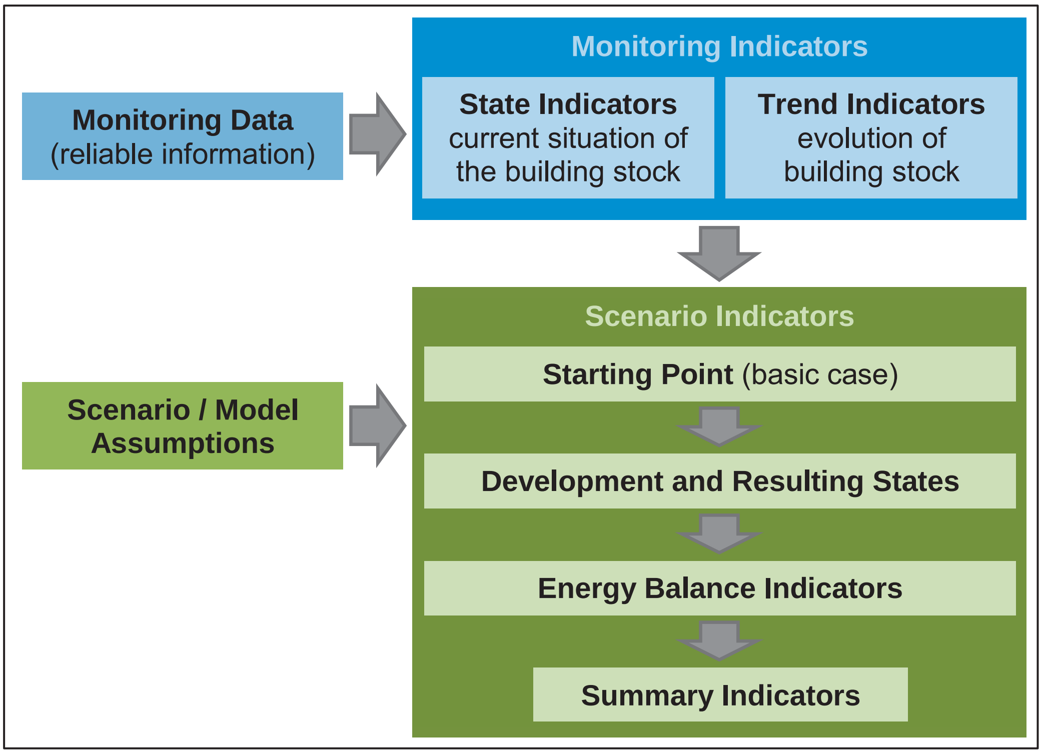


Fig. 3 Overview of the EPISCOPE scheme of energy performance indicators for the monitoring of building stocks

During the EPISCOPE project, a general monitoring scheme has been discussed [16], but with regards to the scenarios conducted, no common calculation scheme was applied. Apart from three commonly defined “summary indicators” – CO_2 emissions, total heat demand, and corresponding CO_2 emission factors – it was therefore possible for the project partners to adjust the commonly defined scheme according to their needs and individual procedures. In this context, it has to be noted that the use of reference quantities varies throughout different case studies and different countries; e. g diverse reference floor areas (living space, gross floor area, net floor area) are in use, shares of certain quantities might be related to the number of buildings or the number of dwellings or some reference area, final energy consumption to the gross or the net calorific value. Hence, comparing indicators from different origin needs to be handled with care.

Because of the key function and high relevance of monitoring data, only reliable indicators, derived by well-established data methods and sources should be applied. During the EPISCOPE project a focus was laid on the discussion of currently available data sources, data gaps and possibilities to improve the information base.

3. Discussion of currently available data sources on residential building stocks

Depending on the size and other surrounding conditions of the building stock concerned (e. g. ownership structure), different sources are available and/or applicable for building stock modelling [17], e. g.:

- Official statistics, census data,
- Building cadastres,
- Data bases from municipalities,
- Data bases from housing companies,
- EPC data bases,
- Data bases containing information on subsidy programs or tax deductions,
- GIS data, aerial images, street view,
- Architectural drawings,
- Consumption data from suppliers (gas and electricity).

Detailed information on all (or almost all) buildings of a building stock observed (complete sample) is thereby accessible in few particular cases only. This ideal situation is basically limited to building stocks owned or managed by housing companies, very small building stocks, or stocks including buildings with similar characteristics. Two of the local case studies undertaken during EPISCOPE in the Czech Republic and in France dealt with housing stocks owned and/or managed by housing companies and it was possible to assess data for the complete building stocks. In the Czech Republic the private database and archives of the local facility management company MRA was used, including spreadsheets displaying useful information like rough geometric characteristics, total heated area, number of floors, number of apartments, construction date as well as heating consumption data for all buildings connected to the district heating network (> 90 % of the housing stock). The main data source for the French case study, dealing with the building stock of the social housing company OPHM, were energy performance certificates which were available for all buildings considered. But because of inconsistencies and incomplete records, the exploitation of the data given turned out to be more difficult than expected, and the respective knowledge gaps had to be filled with assumptions.

Energy Performance Certificate (EPC) Databases were also used for the local case study in Ireland, regional case studies in Austria and Italy, and the national case study in Greece. Independent from the size of the building stock, they may serve as a valuable information basis, especially for specific subsets of the building stock (e. g. new buildings). But with regard to the task of monitoring a complete building stock, they show some flaws:

- EPC data are not necessarily comprehensive: depending on the type of certificates and the level of detail of records, some of the necessary information might not be included in the certificates and therefore in the data base. In Austria e. g. only mean U-values are collected, but not the U-values of individual building elements. Therefore also the share of building element areas refurbished or replaced windows cannot be deduced.
- The EPC database may not represent an unbiased sample for a certain building stock. EPCs are basically issued at special occasions (sale and rent / new buildings / major renovation), which might correlate with the buildings' condition. But for an unbiased sample a selection process not depending on the properties of the objects is necessary. Therefore, although data for a certain share of buildings or dwellings are available (e. g. 33 % of dwellings in the local case study from Ireland), the database does not represent the entire stock from a statistical point of view.

For this reason, EPC databases include significant information, but generally speaking they do not provide all necessary data needed for the regular monitoring of a complete building stock. These findings are in line with the conclusions of the EU project DATAMINE, during which EPC data to monitor building stocks have been analysed [12].

As an example for a collection of data presumably not correlating to building conditions the Dutch SHAERE monitor can be named. This collective database has been established to monitor the progress in the non-profit housing sector in terms of energy performance and energy savings in the Netherlands (SHAERE = Sociale Huursector Audit en Evaluatie van Resultaten Energiebesparing – in English: Social Rented Sector Audit and Evaluation of Energy Saving Results). Since 2010, when the database became operational, housing associations report their stock in the beginning of each calendar year accounting for the situation on December 31st of the previous year (e. g. in the beginning of 2015 for December 31st, 2014). The SHAERE database contains the necessary information per home to calculate an Energy Index. The data imported include physical characteristics and installations of the dwellings in order to be used for their energy labelling. The majority of housing associations participate in the monitor. For 2013, data representing 64 % of all dwellings in the total non-profit housing stock were available [18].

In practice, it will not be possible to establish a similar approach for building stocks with a high share of individual single owners. In these cases the use of representative surveys as alternative or additional data source is to be recommended.

Carrying out sample surveys is a standard method for the acquisition of reliable data, especially if the collection of data for the complete building stock would cause too much effort and cost. Following the principles of sampling theory, representative data of a building stock can be attained by a sample survey of buildings (or dwellings): It should be assured that (in principle) every building (or dwelling) included in the building stock considered has a chance of being selected, that selection of buildings is done by random sampling only and that for all selected buildings the probability of selection is known. Under these circumstances unbiased results can be expected and the statistical standard errors as a measure of significance of the derived expectation values can be calculated.

Due to lack of other data sources, own surveys were undertaken by some of the EPISCOPE partners contributing data to local case studies in Belgium, Cyprus, Hungary, Ireland, and Serbia. In other cases (England, Germany, Norway, Slovenia), data from national sample surveys were available.

E. g. the Slovenian national registry REN [19] is an important data source providing renovation rates related to the building envelope up to 2007/2008, when a national survey was deduced. For the time after 2008 less convenient data sources (data on subsidised measures) had to be used in addition. The situation is comparable to the one in Germany where a national survey was carried out 2009/2010 describing the German residential building stock in its state at the end of 2009 and delivering annual trends as mean values of the period 2005-2009 [7]. No follow-up survey has been carried out so far, and the development from 2010 onwards is insufficiently documented. As already shown in section 2.1, one data collection, even if it is comprehensive, is not sufficient. To monitor a development over time, the data collection needs to be repeated on a regular basis.

An exceptional example providing high data quality is the English Housing Survey (EHS), a continuous national sample survey of the condition and energy efficiency of housing in England

[20]. The survey collects detailed data on all aspects of a dwellings physical characteristics and repair, along with detailed information about the householder. Information about the age and type of fabric and age, type and foe of heating system is collected alongside detailed dimensions and situation of the survey dwelling. The survey can build upon interviews of around 13,000 households per year and a physical inspection of around 6,200 properties per year by qualified surveyors. The data allow the production of annual statistics relating to the fabric and heating systems of domestic buildings. The physical survey data is used to analyse rates of installation of measures such as insulation or heating systems and to create a model of energy and is used to report overall energy efficiency. In addition, further surveys revise fractions of the households already sampled as part of the EHS, e. g. the Energy Follow Up Survey 2011 [21], for which 2,616 households were interviewed in detail about their energy use and behaviour in their home, or the National Energy Efficiency Data-Framework (NEED) [22], which matches actual gas and electricity consumption data, collected for sub-national energy consumption statistics, with information on energy efficiency measures installed in homes, from the Homes Energy Efficiency Database (HEED).

In general, such a kind of comprehensive and broadly based survey approach can be strongly recommended to close existing information gaps, especially on national level. According to the basic meaning of building stock monitoring for climate protection strategies a highly reliable data basis should be aimed at. Of course one large survey cannot alone collect all interesting data and cover the complete requirements of empirical information about housing or energy efficiency in buildings, so supplementary empirical research will still be necessary.

4. Recommendations for a continuous monitoring

As can be seen from the summary above, the initial data situation for different housing stocks varies widely. Therefore, a single standard solution for a continuous monitoring approach cannot be presented. Concepts to improve the situation and to establish regular monitoring with regard to the individual case studies were elaborated by the EPISCOPE partners and are compiled in a synthesis report [17].

Nevertheless, some general recommendations arising from the EPISCOPE case studies can be summarised as follows:

- National house condition and energy efficiency surveys should be established on a regular basis to comprehensively track the energy efficiency of residential housing stocks and enable scenario forecasting.
- Detailed studies should be conducted to record measured energy use in residential buildings on an ongoing basis. The studies need to take account of the wide variation in building types thermal conditions for both new and existing buildings (or dwellings). This will enable calibration factors of predicted energy use to actual energy use to be established.
- The analysis of further databases should also be continued, further developed and cross-referenced to the recommended field surveys and measured energy consumption data processes.
- It will also be important to establish a clear reporting system for monitoring indicators elevated in the residential building sector to establish progress over time and enhance understanding of where policy needs to be aimed in the future to meet targets.

5. Conclusion

It can be summarised that the data situation of European residential building stocks is in general unsatisfactory. In most cases, the information sources available are not sufficient to fulfil the prominent role they should play for climate protection strategies. Currently available data sources often are not representative, incomplete, outdated, and/or inconsistent. As a consequence, there are wide information gaps concerning the actual state as well as the trends of building thermal insulation and efficient / renewable heating systems.

The effort and research on buildings and energy efficiency in the recent years as well as the variety of data sources available might raise the impression that a sufficient database should have been generated somehow by these activities and projects, and the only task is to compile and merge all this information to draw a complete picture. But what needs to be considered is the fact that in publications data gaps are filled with assumptions because in many cases this is the only possible way to proceed.

Therefore, more awareness needs to be created concerning the importance of setting up a reliable information base, because consistent and up-to-date data are needed to form the foundation for the discussion on climate protection strategies in building stocks.

6. Acknowledgements

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Monitoring of the new building of the Ministry for Urban Development and Environment in Hamburg

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Summary

The new building of the Ministry for Urban Development and Environment (BSU) in Hamburg is scientifically monitored by Hamburg University of Technology within the framework of the research initiative EnOB. This paper presents results of the energetic evaluation of the building as well as energy demand and system behavior analysis for the period of October 2014 to September 2015. All results presented in this paper are based on measurement data. Meeting the target value concerning the annual primary energy demand (Q_p = 70 kWh/(m² a)), the target value concerning the annual heating energy demand ($Q_h \approx$ 15 kWh/(m² a)) is exceeded. Nevertheless, comparing the annual heating energy demand with other EnOB buildings, the BSU scores well. The user-specific demand shows a significant part of the total energy demand, while decentralized IT and telecommunications show the largest part of the user-specific demand. Considering the results of distributed fiber optic temperature sensing in the soil, the present difference between heat extraction and heat input has to be reduced to guarantee a long-lasting utilization of the geothermal field.

Keywords: monitoring, measurement data, primary energy demand, user-specific demand, shallow geothermal energy

1. Introduction

The new building of the Ministry for Urban Development and Environment (BSU) in Hamburg, completed in May 2013, is a demonstration project within the framework of the research initiative Energy Optimized Building (EnOB). The guideline are “buildings of the future” with the long-term vision of energy efficient and sustainable buildings, providing high user comfort and being characterized by acceptable investment and operation costs. To examine the fulfillment of these objectives as well as to optimize the operation of buildings, all EnOB demonstration projects are scientifically monitored for at least two years.

The specific energetic target values for the new building of the Ministry for Urban Development and Environment are defined in form of an annual primary energy demand less than 70 kWh/(m² a) and an annual heating energy demand close to 15 kWh/(m² a). The building and energy concept is designed to meet these objectives. Accordingly flaps for natural night ventilation are not motor driven but have to be opened and closed manually by the employees. This effects the compliance of economical objectives in a positive way and can increase the user comfort and satisfaction due to the existing individual opportunity to influence the indoor climate according to [1]. In terms of sustainability the highest DGNB award has already been achieved in 2014. Considering that, among others, the utilization of the geothermal field in a long-lasting way is an important aspect. In the annual energy balance of the soil, heat extraction during wintertime should be as balanced as possible by heat input in combination with natural regeneration of the soil during summertime.

The energy monitoring is based on a detailed measurement concept with approx. 200 energy meters according to EnOB guidelines. In optimization processes regarding energy demand the user comfort should be taken into account as well. Therefore, sensors for detecting, among others, room temperature and humidity as well as CO_2 content are installed in 32 of the approx. 1,500 office rooms. In addition, presence and the individual handling of windows and flaps for night ventilation are detected and recorded as indicators of the user influence in these office rooms serving as reference rooms. Moreover some of the energy piles are equipped with a fiber optic temperature sensing to evaluate and optimize the utilization of soil as heat source and heat sink.

2. Building and Energy Concept

In Figure 1 the architecture of the building is shown. Due to its shape, the building can be subdivided in two low-rise parts of the building consisting of three respectively four sectors with five floors each and one high-rise part of the building with 13 floors. The heated net floor area is 46,557 m². The center of each sector contains an atrium as well as a core area with staircase and elevator, engineering rooms and toilettes while the office rooms are arranged around the center. The facade is developed as unitized facade. Every single element consists of a casement with outside solar protection and inside glare protection system as well as a weather-proofed night ventilation flap and two closed panel systems. In the base area the building envelope is partially realized as fully glazed mullion and transom facade with integrated opaque ventilation flaps [2].

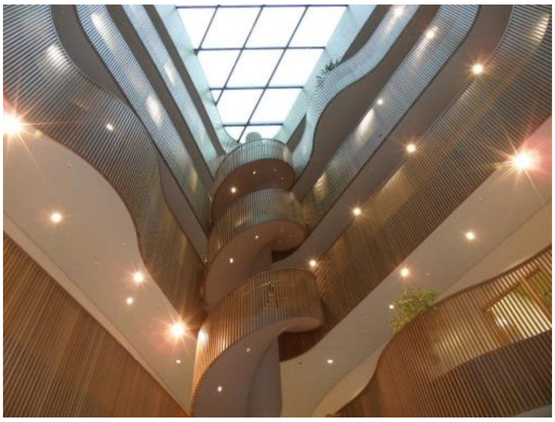


Figure 1: Architecture of the building and atrium, Source: Sprinkenhof GmbH

2.1 System Layout

The system layout in terms of heat and cold supply and distribution is presented in Figure 2. Heat supply is primarily based on using shallow geothermal energy in conjunction with two electrical brine/water heat pumps. Therefore, approx. 950 out of 1,600 foundation piles in total are thermally activated. The heat pumps operate in cascade connection with two power levels each, supplying a total nominal thermal power of approx. 450 kW. Local heating with a maximum thermal power of 750 kW from energy network Wilhelmsburg Mitte is used to cover thermal peak loads and for domestic hot water. Domestic hot water is prepared using the principle of instantaneous water heaters, it is separated for the restaurant and the changing rooms. Two separated hot water storage tanks of 1,500 l each are provided for domestic hot water preparation, while two 5,000 l storage tanks are part of the hot and cold water circuit as shown. Cold supply is primarily based on free cooling through the energy piles as soil heat exchangers with a total thermal power output of nearly 600 kW in combination with free night cooling. Active cooling by the heat pumps is technically possible, but not implemented. During transitional periods, two recooling plants with a total thermal power output of approx. 460 kW can be used for cooling purpose instead of soil-based free cooling. Furthermore, these recooling plants can be used to adjust long-lasting utilization of the geothermal field by additional cooling of the soil. Special functional areas, e. g. data processing rooms and engineering rooms, are air-conditioned by electrically driven split cooling systems. Electricity is provided from the Hamburg Energie power grid.

The office rooms are basically heated and cooled by thermoactive ceilings. In contrast, special functional areas are heated by floor heating systems, convectors and radiators. Each building sector as well as special functional areas like the restaurant has a several air-conditioning unit, designed as a pure ventilation system, equipped with heat recovery unit and operated exclusively during heating period. If needed, supply air is reheated to 20 °C by heating registers, supplied by the heating network. The office rooms are generally provided with supply air, while used air is delivered into the atrium area through overcurrent elements and exhausted there. During cooling period ventilation occurs manually by windows and ventilation flaps.

2.2 Data Acquisition and Measurement Technology

The building automation network is based on LON-standard, the data acquisition system on OPC-standard. LabVIEW is used as OPC-client to record, visualize and save data with a time resolution of 60 s. Thermal energy meters in use are calibrated combined meters consisting of an impeller flowmeter, a pair of resistance temperature sensors and an arithmetic unit. According to DIN EN 1434, the flowmeters as well as the arithmetic units meet accuracy class 2; the temperature sensors are designed as Pt 500 in two-wire circuit. Summing up the measurement uncertainties of these components results in the total measurement uncertainty of a thermal energy meter according to [3], in this case max. ± 9 %. Electrical energy meters in use are calibrated electrical active and reactive energy meters meeting accuracy class B according to DIN EN 50470, meaning max. ± 1 % uncertainty. An optical fiber in conjunction with a specific evaluation unit is used for site-resolved temperature measurements in the soil (DTS – Distributed Temperature Sensing). Its measuring principle is based on backscattering a short laser pulse (< 10 ns) that is coupled into the optical fiber and following Raman spectroscopy on the backscattered light pulse. The spatial association is based on a very precise timing, taking into account the propagation velocity of light in the optical fiber. According to the manufacturer specifications, the accuracy of the whole measuring system is estimated to min. ± 0.2 K [4] [5].

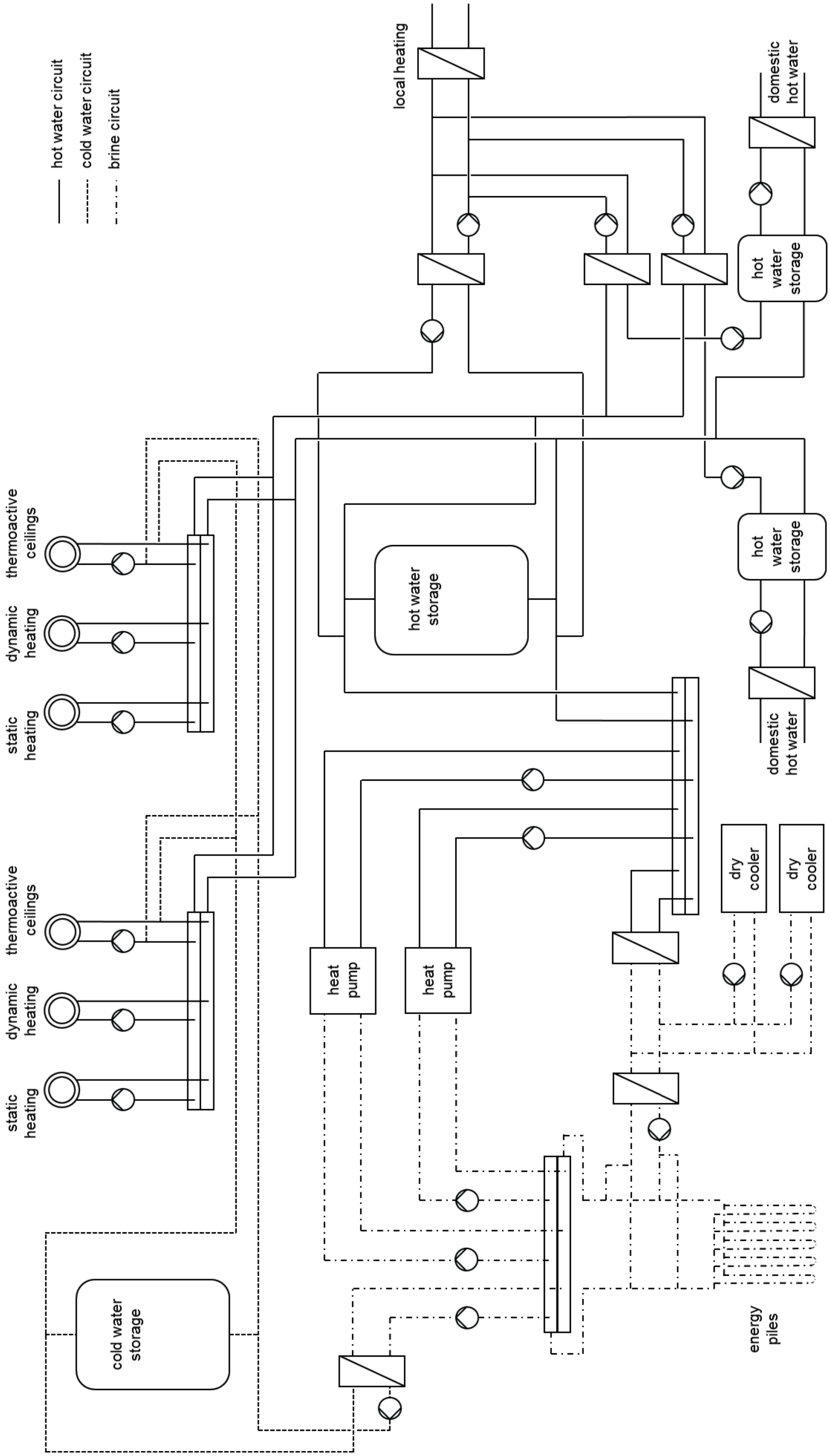


Figure 2: System layout of the BSU-building, heat and cold supply and distribution

3. Monitoring Results

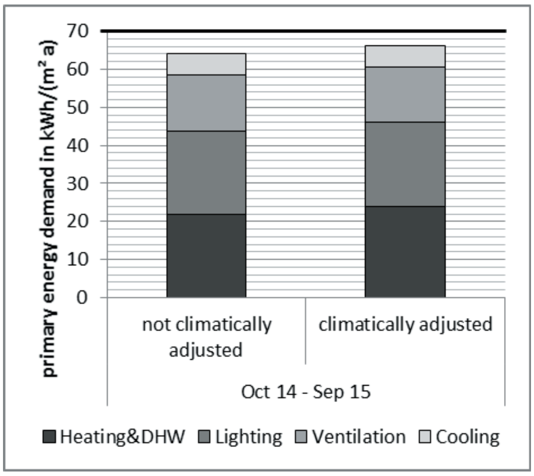
For the period from October 2014 to September 2015 complete and reliable measurement data are available by monitoring the building operations. Selected results of the energetic evaluation as well as energy demand and system behavior analysis based on measurement data are presented.

3.1 Energetic Evaluation

The energetic evaluation of the building is primarily based on the annual primary energy demand and the annual heating energy demand. For both characteristic values corresponding target values according to DIN V 18599 respectively PHPP were determined and approved by thermal simulations during planning phase. The heated net floor area is used as reference. For comparison of measured energy demands with this corresponding target values, the heating energy demand is climatically adjusted according to [6],

$$Q_{\mathrm{h,cl}} = Q_{\mathrm{h,measured}} \cdot \frac{G_{\mathrm{standard}}}{G_{\mathrm{measured}}}, \quad (1)$$

where $Q_{\mathrm{h,cl}}$ describes the climatically adjusted annual heating energy demand, $Q_{\mathrm{h,measured}}$ describes the measured annual heating energy demand, G_{standard} is the number of degree days of an average year at the German reference location Würzburg and G_{measured} is the number of degree days of the investigated period under consideration for the actual location. In this case, degree days of the nearest DWD weather station in Hamburg-Fuhlsbüttel were taken for actual location Hamburg-Wilhelmsburg [7] [8]. With the scheduled boundary conditions and system boundaries according to DIN V 18599, the actual annual primary energy demand should not exceed 70 kWh/(m² a). In Figure 3 the annual primary energy demand is shown, based on measured values. It is 64.05 kWh/(m² a) or 66.30 kWh/(m² a) climatically adjusted and so meeting the target value. According to DIN V 18599, the identified characteristic value contains energy demands in the categories of heating, domestic hot water, cooling, ventilation and lighting. Energy demands that are connected to the building automation as well as controlling and regulation are not included. Due to measurement shortcomings it is not possible to separate energy demands for heating and domestic hot water yet. Therefore, this summarized energy demand contains heat extracted from the soil, electricity demands of the heat pumps, heat from local heating and electricity demands of all central circulation pumps in the heating system (see Figure 2). The energy demand for cooling contains heat input into the soil, heat dissipated by recooling plants, electricity demands of recooling plants, split cooling systems and all central circulation pumps in the cooling system (see Figure 2). Concerning ventilation, only auxiliary energy demands are considered, according to DIN V 18599; considering electricity demands of the ventilators of the 13 main ventilation units in this case. The energy demand for lighting contains lighting demands for office rooms and traffic areas as well as lighting demands of the restaurant; other special areas like the conference room are not included. Determining the electricity demand for lighting is based on corresponding direct measurements in office rooms and traffic areas for selected floors and building sectors and projection on the whole building; electricity demands of the restaurant is recorded separately and completely. Both heat from local heating as well as electricity from Hamburg Energie power grid are generated purely regenerative according to supply contracts by the Free and Hanseatic City of Hamburg. Thus, the primary energy demand would be Q_p = 0 kWh/(m² a) for the BSU-building. However, to achieve comparability between the characteristic value based on measurement data and the corresponding target value, solely the primary energy factor of local heating is assumed to $f_{p,lh}$ = 0, whereas the primary energy factor of electricity is $f_{p,el}$ = 2.6 according to the German Federal electricity supply in 2009 [9].



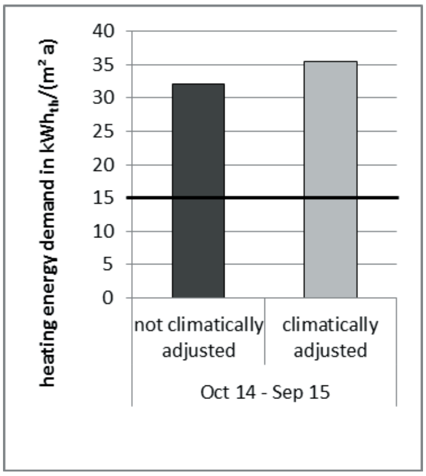


Figure 3: Annual primary energy demand and heating energy demand, not/climatically adjusted

According to the guidelines of the planning package for passive houses (PHPP), the annual heating energy demand should be as close as possible to 15 kWh/(m² a), implying a building envelope to be passive house standard. The heating energy demand is a net energy demand by definition, which cannot be detected by measurement. Thermal energy metering at both heating circuit manifolds were chosen to achieve the most appropriate comparative measurements (see Figure 2). Thus, generation losses and storage losses are completely and distribution losses are partly excluded from consideration. Nevertheless, measurement data still include unneglectable remaining distribution losses and delivery losses. The annual heating energy demand, based on actual measurement data, is shown in Figure 3. It is 32.14 kWh/(m² a) or 35.46 kWh/(m² a) climatically adjusted. Taking into account aspects as mentioned before, the target value is significantly exceeded. In this context, optimization potential is provided, among others, by heat recovery of the ventilation units. Heat recovery efficiencies achieved so far during operation are on average about 52 % to 58 % at all units and thus do not meet the target value of 75 %, considering the heat recovery efficiency related to outside temperature,

$$\mathrm{HRE} = \frac{t_{\text{used air}} - t_{\text{out}}}{t_{\text{supply air}} - t_{\text{out}}} . \tag{2}$$

Nevertheless, the annual heating energy demand of the BSU-building is low in comparison with other EnOB buildings. Figure 4 shows the comparison of annual heating energy demands for different EnOB buildings. Especially these buildings are suitable for comparison due to similar concepts and use as well as similar dimensions. But this comparison is still merely suitable for a rough estimation, because exact boundary conditions and system boundaries of the other projects are not known in detail. Data are taken from EnOB data base “demonstration buildings” [10]. The characteristic values shown are not climatically adjusted, implying certain uncertainties due to different evaluation periods with differing weather conditions.

3.2 System Analysis

An important part of the total energy demand of a building is the so-called user-specific demand (USD), including any energy demand connected to the individual use, but not to the building itself. In this case, the user-specific demand contains electricity demand of dataprocessing-rooms (DP-rooms), decentralized IT and telecommunication in the office rooms, elevators and tea kitchens. The user-specific demand is basically not considered in energy demand calculations according to

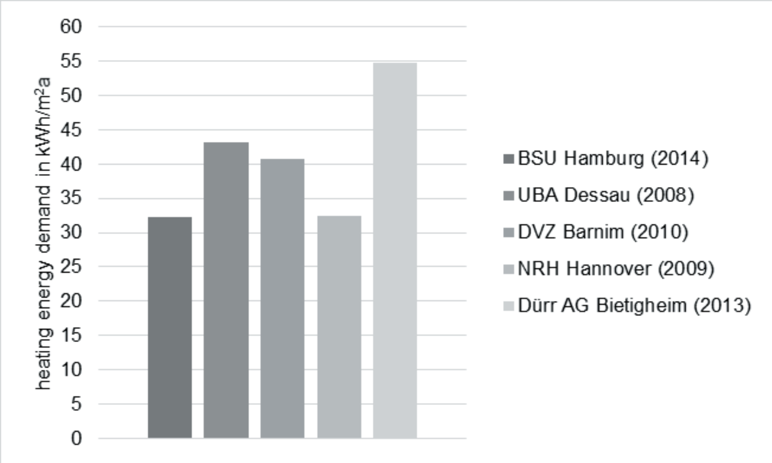


Figure 4: Annual heating energy demand for different EnOB buildings, not climatically adjusted

DIN V 18599, because it is not possible to estimate and predict user-specific demand reliable in general. Contrasting actual measured values with the corresponding target values, user-specific demand is not included and has to be removed if necessary. But however, its part of the total energy demand is unneglectable, especially for large office and administration buildings. The annual profile of the total energy demand including USD is shown in Figure 5. During wintertime the share of USD is approximately 10 % to 15 % and 30 % to 40 % during summertime. Regarding the total electricity demand the share of USD increases by 25 % to 30 % during wintertime and 45 % to 50 % during summertime. The large differences in the percentages of USD result from the high electricity demands of the heat pumps during wintertime. If USD would be included in the determination of the primary energy demand the characteristic value of the primary energy demand would be 102.29 kWh/(m² a) or 104.54 kWh/(m² a) climatically adjusted. Referring to Figure 6, the electricity demand of decentralized IT and telecommunication in the office rooms account for the largest share. It is determined by direct measurements of sockets in office rooms for selected floors and building sectors and projection on the whole building, primarily including electricity demand of height-adjustable desks, computers, screens and phone systems.

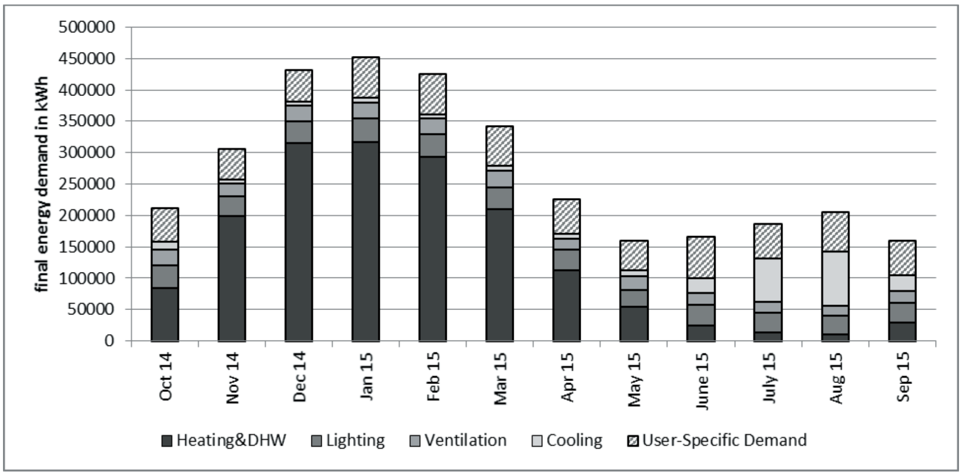


Figure 5: Composition of the total energy demand including user-specific demand

As a feature of this project 17 energy piles as well as 13 boreholes in- and outside the geothermal field are equipped with an optical fiber for spatial resolved temperature measurement. Figure 7 shows temperature profiles dependent on time and depth, exemplarily for one energy pile. These temperature profiles show periods of heating and cooling mode dependent on the ambient temperature both during the day and year as well as regeneration cycles during the day and at the

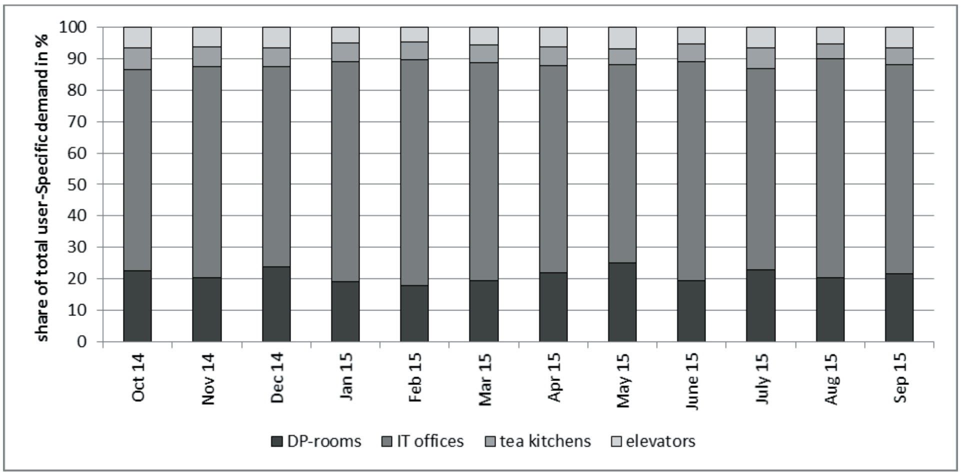


Figure 6: Composition of the user-specific demand (USD)

weekends. Natural regeneration of the soil is supported by heat input during summertime via free cooling trying to achieve the temperature level at the beginning of the previous heating period, ensuring a long-lasting geothermal utilization. If necessary, occurring disproportions in terms of insufficient heat extraction in contrast to heat input can be balanced in moderation by the recooling plants. In this case, heat out of the soil is dissipated to the environment by the recooling plants at the end of a heating period. In addition, heat input during cooling periods can be reduced by switching from free cooling via soil to cooling via recooling plants if the ambient temperature is sufficiently low. After the first year of operation and corresponding measured data, the temperature level at the beginning of the actual heating period is approximately 1 K lower compared to the previous year.

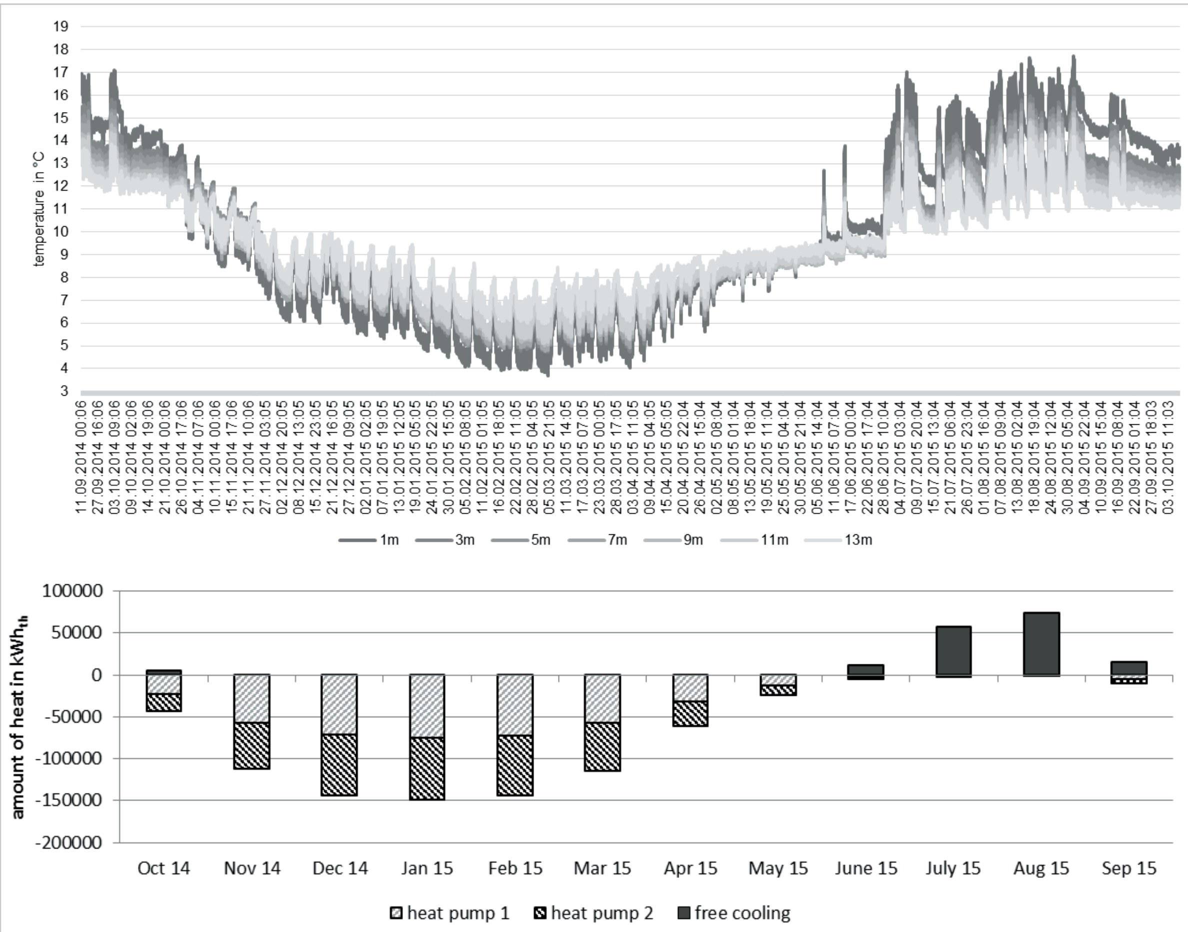


Figure 7: Long time temperature profile of one energy pile and annual energy balance of the soil

Thus, deduced for the moment, heat extraction during wintertime exceeds natural regeneration in combination with heat input during summertime. In this case, only modifications of operation modes based on experiences in the context of the initial operation process enable to achieve an adjusted annual balance. Modifying the temperature limit value of heating mode in connection with modifying parameters of heating and cooling curves is one step to optimize the annual balance of the soil by the cooling period. Possible retroactive effects on the user comfort have to be considered. Regarding the monitoring project, reviewing the temperatures in the geothermal field is a central task. In Figure 7 monthly heat amounts brought into and extracted from the soil are shown as well. Heat input is measured directly, for heat extraction corresponding direct measurements at the heat pumps are first available for the present heating period. The plots were determined indirectly, using measured electricity demand of the heat pumps and heating energy delivered by the heat pumps to the heating circuit of the building. The amount of heat brought into the soil is only a fractional part of the annual heat extraction, considering the period of one year. Nevertheless, this comparatively small amount of heat brought into the soil leads to a significant increase in temperature as shown.

Figure 8 shows the long time temperature profile of the soil in different depths close to the geothermal field. Up to a depth of approximately 10 m, the temperature in the soil significantly varies during the year, resulting primarily from the influence of the ambient temperatures dependent on the season. Due to storage capability of the soil, increase and decrease in temperature is damped and slightly delayed to the ambient temperature profile. Below a depth of approximately 10 m the temperature in the soil is nearly constant at 11 °C. Thus, the surrounding soil is not influenced significantly by the usage of the geothermal field.

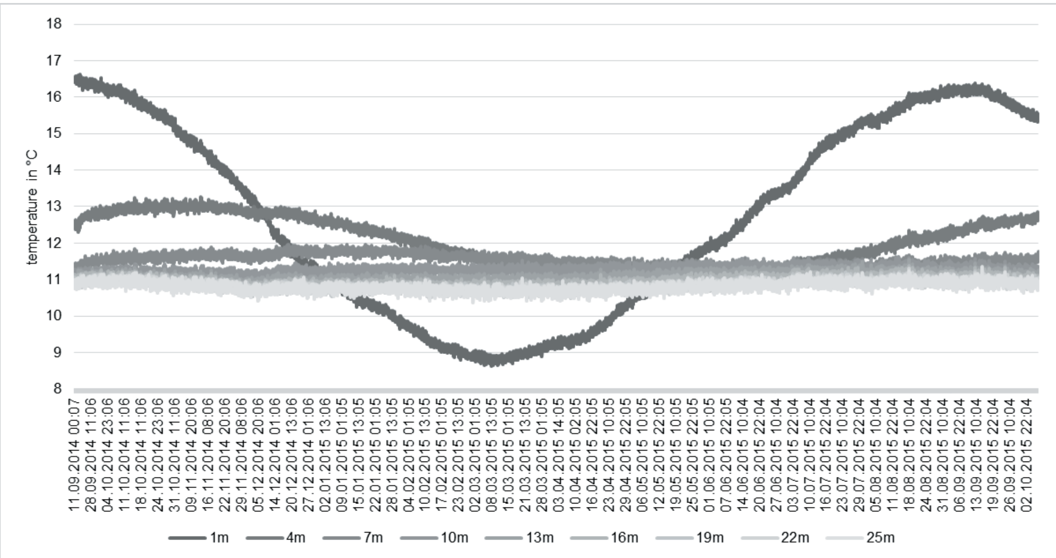


Figure 8: Long time temperature profile of the soil close to the geothermal field

4. Conclusions

Despite some implemented optimization measures, the actual measurement data based annual heating energy demand of the BSU-building is more than twice as high as the prescribed target value of the planning phase. Nevertheless, the actual annual heating energy demand of the BSU-building is quite low in comparison with other energy efficient buildings of similar size and usage. The objective to achieve passive house standard for the building envelope of a building with unitized facade and corresponding size and complexity does not seem to be compatible with reality. Overestimating internal heat gains seems to be one reason for a significantly less heating energy demand estimated in the planning phase.

The user-specific demand represents a significant part of the total energy demand of the BSU. This knowledge seems to apply especially for large office and administration buildings in general. For the BSU decentralized IT and telecommunication shows by far the largest part of the USD. Thus, implementing energy efficient computers, screens and phone systems is one simple but effective measure achieving a low total energy demand, especially regarding primary energy level.

The amount of heat brought into the soil during cooling period is low compared to the amount of heat extracted from the soil during heating period. Nevertheless, the temperature level in the soil is significantly increased by the heat input. Therefore, summer heat input is a useful and important addition to natural regeneration of the soil. Achieving a leveled annual energy balance of the soil in terms of a long-lasting utilization of the geothermal field seems to be possible in the context of further optimization measures. These are optimization measures in terms of enlarging operation in cooling mode and further reduction of the heating energy demand in connection with available possibilities to adjust heat extraction and heat input specifically by recooling plants.

5. Acknowledgement

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Naturalism in Architecture

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Summary

Naturalism is the philosophical belief that everything arises from natural properties and causes, and supernatural or spiritual explanations are excluded or discounted. Adherents of naturalism assert that natural laws are the rules that govern the structure and behavior of the natural universe [1]. In the twentieth century, naturalism has had a great impact on architecture. It is the stimulator of organic, green, sustainable, and ecological architecture, which are different movements in the field.

1. Introduction

Extensive biological researches and the evolution of natural sciences in the end of the nineteenth century and the beginning of the twentieth were the contributing factors to the domination of naturalism. Books like Buffon's “Natural History” that was published in 1749 discussed the theory of evolution. Xavier Bichat’s “Physiological Research in Life and Death” that was published in 1800 introduced the term ‘organic’ for the first time in printed publications [2].

The world's first publication about the evolution theory is written by Lamarck. He disagrees with Buffon's theory by stating that the environmental changes cause evolution. In his book, published in 1800, Lamarck introduces the term ‘biology' [3]. In the same year Goethe brings up the term 'morphology'. He applies his ideas about his theory on art, architecture, active dynamic shaping in all living organisms. He also explains morphology more by exploring changes in the shapes of non living things like rocks and fossils.

Darwinism is another theory of biological evolution. It states that all species of organisms have evolved through natural selection [4]. The Darwinian Theory included the broad concept of evolution and gained general scientific acceptance after Darwin published “On the Origin of Species” in 1859. In “On the Origin of Species”, Darwin does not rule out Lamarckism as a supplementary mechanism to natural selection. He calls his Lamarckian hypothesis ‘pangenesis’ [5]. He explains it in the final chapter of his book “Variation in Plants and Animals under Domestication” after he describes numerous examples to demonstrate what he considered to be the inheritance of acquired characteristics.

Lamarck claims that changing surroundings changes living organisms. These changes are then transmitted by heredity. Darwin, however, emphasizes that change is always spontaneous and by chance. He continues on with the idea of “survival of the fittest”, where the fittest of all adapts to the environmental conditions and survives the changing environment. This created a debate among biologists for more than 50 years about whether form follows function or vice versa. The theory of evolution and modern biological researches are considered the main contributing factors that have deviated architecture from classic to modern. This is through aspiring to become similar to nature and its forms as well as adapting to it.

2. Methodology

This paper studies different architectural movements influenced by nature and its features. It identifies their stimulators and development regarding the design processes, materials, motifs, and basic ordering principles. Architectural movements are classified into these different categories based on the characteristics they share.
The different categories are labeled such that a comparison can be easily made. Since different styles may share some characteristics, the labels may overlap and the architectural designs could even be classified into more than one category.

This research identifies:

- different architectural styles influenced by nature;
- characteristics that distinguish different styles;
- examples of architects who are associated with each style;
- examples of buildings associated with each style;
- contributing factors to the development of each style;
- The connection between changes in natural theories and their corresponding changes in architecture.

My aim is to critically examine the notion of naturalism by rereading architectural movements, influenced by nature and biological theories, such as terms, models, projects, and building. This is for better understanding of the present discourse.

3. Different Architectural Styles:

3.1. Organic Architecture

The organic theory is considered one of the first trends that have deviated architecture from its classic trends to modern trends. This is through aspiring to become similar to nature and its forms as well as adapting to it. Organic architecture is one that promotes harmony between human habitat and the natural world. This is through design approaches that are well integrated with their location, such that buildings, furnishings, and surroundings become a unified, interrelated composition.

The main result of this architectural movement is the Sullivanesque style, named after Louis Sullivan. His interest in nature appears in his ideas and work especially with his slogan 'form follows function'. He claims that the function of a building is the reason for its existence. Its design is generated from and reflects its function.

The large impact of naturalism shows in Frank Lloyd Wright’s work. He was embedding the term “organic architecture” into the all his design processes, materials, and basic ordering principles such that they repeated themselves throughout the buildings as a whole. The idea of organic architecture doesn't only refer to the building. Not only is the “literal relationship to natural surroundings, but how the buildings" are geometrically designed is carefully thought about as if it and the environment were unified.

Wright was articulated by his cryptic style of writing as well. His statement says: "So here I stand before you preaching organic architecture: declaring organic architecture to be the modern ideal and the teaching so much needed if we are to see the whole of life, and to now serve the whole of life, holding no traditions essential to the great tradition. Nor cherishing any preconceived form fixing upon us either past, present or future, but instead exalting the simple laws of common sense or of super sense if you prefer determining form by way of the nature of materials"[6].
"Using Nature as our basis for design, a building or design must grow, as nature grows, from the inside out. Most architects design their buildings as a shell and force their way inside. Nature grows from the idea of a seed and reaches out to its surroundings. A building thus, is akin to an organism and mirrors the beauty and complexity of nature" [7].

A well known example of organic architecture is falling water, the residence Frank Lloyd Wright designed for the Kaufmann family in rural Pennsylvania [8]. Wright had many choices to locate a home on this large site, but chose to place it directly over the waterfall creek. This created a close noisy dialog with the rushing water and the steep site. The horizontal striations of stone masonry with daring cantilevers of colored beige concrete blended with the native rock outcroppings and the wooded environment.

Fig.1 Frank Lloyd Wright, Falling water, Pennsylvania 1935-1939

The Solomon R. Guggenheim Museum in New York City occupied Wright for 16 years (1943–1959) and is probably his most recognized masterpiece. The building rises as a warm beige spiral from its site. Its interior is similar to the inside of a seashell. Its unique central geometry is meant to allow visitors to easily experience Guggenheim's collection of paintings by taking an elevator to the top level and then viewing artworks by walking down the slowly descending, central spiral ramp, the floor of which is embedded with circular shapes and triangular light fixtures to complement the geometric nature of the structure.

We now know that architects who have been affected by organic theories have taken two paths. One deals with the building as an organism that grows and evolves based on the needs of users and the compatibility with all elements of nature, and the anomalies on the surrounding environment. The second uses formal and functional features, inspired by organisms like plants with their roots, stem, and leaves; or organisms like snails, fungus and mushroom [9].

3.2. Metabolism

Metabolism is a post war Japanese architectural movement that fused ideas about architectural mega structures with those of organic biological growth. Its first international exposition was during CIAM’s 1959 meeting and its ideas were tentatively tested by students from Kenzo_Tange’s MIT studio [10].During the preparation of the 1960 Tōkyō World Design Conference, a group of young architects and designers, including Kiyonori_Kikutake, Kisho Kurokawa, and Fumihiko Maki, prepared the publication of the metabolism manifesto. They were influenced by a wide variety of sources including the Marxist theories and biological processes. Their manifesto was a series of four essays titled: Ocean City, Space City, Towards Group Form, and Material and Man. They also included designs for vast cities that floated on the oceans and plug in capsule towers that could incorporate organic growth. Although the World Design Conference gave the metabolism architects exposure on the international stage, their ideas remained theoretical [11].

Metabolists develop their organic schemes to respond to changing activities. Metabolism is the belief that design and technology should express the vitality of living organisms. The basis of the ideas adopted by metabolism architects results from the idea that everything in life changes and is altered by rapid technological developments. As a result of the changing human needs, buildings must adapt their spaces to the new activities. This requires them to be able to change and grow as a living organism. The icon of Metabolism, Kurokawa's Nakagin Capsule Tower, was erected in the Ginza district of Tōkyō in 1972 and completed in just 30 days. It was prefabricated in Shiga Prefecture in a factory that normally built shipping containers. It is constructed of 140 capsules plugged into two cores that are 11 and 13 stories in height [12].

Fig.2 Kisho Kurokawa, Nakagin Capsule Tower, Tokyo, Japan, 1972

3.3. Mega structure

Mega structure is also an architectural concept popularised in the 1960s where a city has a single building or a relatively small number of interconnected buildings. Such arcology is popular in science fiction. Mega structures often play a part in the plot or setting of science fiction movies and books.

The idea of mega structure is like the natural evolution of the organic idea with respect to growth and development. Different parts of the same organism work in the same mechanism as flowers, leaves, and fruits that grow from one tree. Huge technological development in the 1960s helped with the development of that idea. The first two definitions of megastructure were given by Fumihiko Maki in "Investigations in Collective Form". He defined it saying that "the artificial landscape is 'made possible by present day technology,' but its giant infrastructure is supposed to serve as 'the great hill on which Italian towns were built'" [13]. Maki also mentions the definition of megastructures that was given by his Professor, Kenzo Tange. He states that it "is a form of architectural forms, the Mass human scale and self serving, separate units gathered rapidly changing during the larger structure" [14].

Early examples of these constructions and spatial forms were held in Montreal Expo Canada (1967). The exhibition of these facilities could be extended to cover the whole exhibition hall in one giant building. It is an example of spatial structures of classical history. It is designed to be a number of spaces adaptable to any activity and linked by escalators, making a giant urban space in multiple storey's. Technological development includes several factors like construction and structural elements of central capsules. These created huge cumulative and mixed major units and sub units. All of these underline the strong influence of organic theory and expressed by cutting edge technology.

Fig.3 Kenzo Tange, Yamanashi Culture Chamber, Kofu, 1967

3.4. Eco architecture

In the late nineteenth century and early twentieth century the human consciousness has globally identified the effects of the industrial revolution on the global environment. The concept of environmental preservation has become mainstream [15]. Hence, architects had to take a stance. They compromised architecture, urban context, environmental fabrics, and therefore, the concept of appropriateness [16]. Pressure on governments by active groups and green parties in Europe and America has increased especially in the 1970s and 1980s. Scientist state that water problems dropped to less than half with population increase, particularly in the Middle East, Africa and India [17].

In the late two decades, a set of architectural trends emerged. These try to sync with the natural variables in order to achieve the concept of sustainable development as defined by "The World Commission on Environment and Development" in 1992. Its report (our common future) aims to get the needs of the present without compromising the future generation's right in finding needs [18]. The most important of sustainability objectives, which tends to preserve the architectural heritage, is to be able to access managed and maintained buildings under the socio economic conditions. The most important thing of these features is to be compatible with its surroundings and environment, conserve natural sources, and blend with all successful art forms. This encourages individuals and the society to preserve, respect and make good use of the environment. Sustainability popped due to architectural treatments to local environmental conditions. Eco architecture is therefore also called green architecture. It requires a lot to keep the energy and biological comfort and take advantage of available natural resources with the use of environmental technology [19].

Green architecture is inspired by plants and their natural life cycle and their impact on man and the environment together as they convert carbon dioxide to oxygen and enhance the environment quality [20]. The buildings are hence also useful to man and the environment. Some buildings even have a full system called “the Building Life Cycle”. Green architecture uses natural resources like the sun and air. It provides people's demands on public health and comfort. It reduces costs and increases productivity in all architectural spaces. It also increases environmental awareness in construction, water consumption and wastewater recycle [21]. Green architecture uses architectural elements to allow the entry of air into spaces. It also takes advantage of the sun in lighting and ventilation by using solar tubes. This reduces the need for electric power generation and hence reduces pollution [22].

Fig.4 Norman Foster, Commerzbank Headquarters, Frankfurt, 1991-97

Norman Foster's architecture has a sophisticated influence on nature. Foster deviated from the traditional design solution in skyscrapers that used to have ground floor offices wrapped around one central building. He designed the Commerzbank Headquarters in Frankfurt (1991 97). Foster has designed the building such that it can open to allow natural air to enter. The central atrium also allows natural air to ascend. Sky Gardens also provide high floors and set a fixed rate of natural ventilation. In order to obtain maximum benefit from natural ventilation techniques, computers are used to monitor weather conditions and adjust the size of the air inside the building and change the temperature during the day Norman Foster's Swiss Reinsurance Headquarters Building Company in London provides natural ventilation on most days of the year. It also reduces energy consumption and carbon dioxide emissions through natural convection [23].
Under the increased awareness of the negative effects of environmental pollution and the resulting problems, naturalism peaked at the end of the twentieth century and the first decade of the 21st century. This lead to the emergence of the thought of sustainable architecture that is compatible with the environment [24]. This is to compensate the environmental destruction resulting from advanced technology.

3.5. Sustainable Architecture

By the 1980s, as a result of great technological development and pollution, the interest in the natural environment increased. Architecture started seeking for compatibility with the surrounding environment without harming the natural environment and climate. There have also been persistent attempts to develop architecture and accommodate it with the requirements of the times and the needs of users. Sustainable architecture supports the environmental balance by relying on ecological systems. Building materials can be reused to reduce the consumption of natural resources to meet the needs of the present generation without compromising the ability to meet the needs and requirements of future generations. Sustainable architecture blends natural resources with art form and architectural composition that gives the expressive features [25].
Automated factors, which have recently become an essential component in the composition of building, cannot be overlooked. Some energy saving elements are added on buildings like the World Trade Tower in Manama, Bahrain. This building uses three dimensional design turbines to generate power for the building. Automated factors also appear in the form of mechanical elements such as elevators, electrical and HVAC systems, generators, building management systems, and others. All these elements, which became under the current conceptual vision are of the main factors of building design.

Fig.5 Atkins, World Trade Center, Manama, Bahrain, 2008

3.6. Green architecture

Green architecture, also known as green design, is an approach to building that minimizes harmful effects on human health and the environment. Green architecture attempts to safeguard air, water, and earth by choosing *eco friendly* building and construction materials [26].In the last two decades, substantive interaction occurred between architecture and the environment. Green architecture is related to the economics of energy. The similarity is in the growing importance of energy issues and environmental conservation. This produced the green architecture theory with foundations and principles based on rates and bioclimatic measurements. It aims to achieve a balance between human needs and the surrounding environment, making it one of the most important architectural treatises since the end of the twentieth century.

Architects seek compatibility with the environment and try to improve the efficiency of energy flow in buildings. Also, improvements are made to the transition from static to dynamic forms in order to meet the requirements of energy conservation. One of the concerns of the green architecture is to reduce the negative environmental effect of the building, the cost of construction, and the negative effects on the environment. This is done by using sophisticated technology. Nature inspires architects though plants, animals and natural elements in the universe, such as the mountains, wind, water, rocks, and their products. Not only did their appearance inspire them, but also the way they operated. This interest applies in the work of Santiago Calatrava, Renzo Piano, Richard Rogers, Nicholas Grimshaw, and others.

Fig.6 Renzo Piano, California Academy for Sciences, USA, 2005

3.7. Smart Architecture

Smart buildings deliver useful building services (illumination, thermal comfort, air quality, physical security, and sanitation) that make occupants productive at the lowest cost and environmental destruction over the building lifecycle. Reaching this vision requires adding intelligence from the beginning of design phase to the end of the building's useful life. Smart buildings use information technology during operation to connect a variety of subsystems, which typically operate independently to optimize total building performance. They are connected to the smart power grid, and they interact with building operators and occupants to empower them with new levels of visibility.
In the second half of the twentieth century, modern computer science used sophisticated methods to do the work. This science is known as artificial intelligence. Computer technology reflects on all aspects including architecture. The building has become the closest thing to living organisms. It thinks, moves, monitors changes around it and inside it, and expects what the occupants will act upon it [27].Expanding applications use artificial intelligence. In the early 1980s, artificial intelligence was introduced into all aspects of life. Information technology (IT) and building management systems (BMS) merged to be the result called intelligent buildings.

Intelligent buildings are ones smart enough to use artificial intelligence. They could therefore hold some qualities of human beings. They respond and have automatic reaction mechanisms to certain conditions and variables. Their effective capacity to adapt to internal and external environmental variables changes daily and seasonal situations.

Fig.7 Norman Foster, City Hall, London, 2002

4. Conclusions

Naturalism has influenced architecture in different ways. Its different aspects created several architectural approaches, organic, green, sustainable, ecological architecture. All kinds of architecture are conceptual tools that evaluate models derived from nature and ecosystem. They also provide a framework for conceptualizing environmental and technical issues. Different approaches in architecture are inspired by nature and it's sustainable, conserving, diverse, flexible, and adaptable qualities. Architectural movements are influenced by nature and new natural science theories. This inspiration had created a different approach in dealing with architecture. Architecture is also translated into design process, materials, motifs, and basic ordering principles.

Sustainable architecture was driven by a search for a new architectural language and, at the same time, is a poetic expression of naturalism. Sustainable architecture has received media attention in the whole world. It has generate an enormous interest in architecture in general. It aims to solve the issues that came with the rapid *change* in climate, anticipated effects like the increasing global temperature, rising sea levels, changing precipitation, and expansion of deserts in the subtropics. Sustainable architecture supports the environmental balance by relying on ecological systems and building materials can be reused to reduce the consumption of natural resources. Sustainable architecture and its systematic conceptual approach would have to broaden the narrow view of materiality and technology towards a fundamental rethinking of environment and nature.

Beyond nations and states, what could a desired future version of this be? Architectural schemes would emerge and go beyond the metaphor and function and living organisms behavioral approaches to address effective designs for adaptation to change. Architects would build new alliances and reorganize their work in trans disciplinary practice. Sustainable architects and designers will learn from their architectural practice in solving environmental problems in buildings and cities and landscapes and address a variety of spaces for new commonalities, aesthetics, and environmental values. The below table summarizes the differences between how architectural movements were inspired differently by living organisms and their features.

Table1: Different Architecture Approaches Inspired by Nature

Architecture Style	Function	Form	Structure	Adoption	Conservation	Reproduction	Response
Organic	•	•	•				
Metabolism	•	•	•	•			
Mega Structure	•	•	•	•			
Green	•	•	•	•	•		
Sustainable	•	•	•	•	•	•	
Smart	•	•	•	•	•	•	•

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Networking Intelligent Cities for Energy Efficiency – The Green Digital Charter Process and Tools

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Summary

The Green Digital Charter (GDC; http://www.greendigitalcharter.eu) is a declaration committing signatory cities to use information and communication technology (ICT) to address climate change issues ("ICT for green") as well as improve their resource management ("greening ICT"). In the course of the FP7 funded NiCE (Networking intelligent Cities for Energy Efficiency) project under the lead of EUROCITIES an action framework, application guidance, and monitoring tools were developed and best practice exchange, learning and networking activities organised. Four research and practice partners and five partner cities (Bologna, Eindhoven, Linköping, Manchester and Warsaw) were involved. The paper presents the elements and implementation of the toolkit and the results of a follow up survey of signatory cities on progress and challenges of GDC implementation.

Keywords: ICT, energy efficiency, smart cities, climate change, resource management

1. Introduction

Cities today face the unprecedented challenge of achieving environmental, social and economic sustainability. One of the core challenges on this way is tackling carbon emissions. Information and Communications Technologies (ICT) have an important part to play in this process: They are an enabling technology ("ICT for green") as well as an energy consuming infrastructure themselves ("greening ICT"). The Green Digital Charter (GDC; [1]) is a declaration committing signatory cities to deliver on the EU climate objectives through the innovative use of ICT. Signing the Green Digital Charter allows for both political commitment and a step-by-step practical process, so cities can use ICT to address climate change issues, as well as improve their resource management, cooperate with other cities and stimulate their economies and citizens' wellbeing. Today (2015) 46 cities are GDC signatories [2].

NiCE (Networking intelligent Cities for Energy Efficiency) was an FP7 funded project under the lead of EUROCITIES to support cities in the achievement of their goals as outlined by the Green Digital Charter [3]. Four research and practice partners and five "reference cities" (Bologna, Eindhoven, Linköping, Manchester and Warsaw) were involved. NiCE is supporting cities in three key areas:

- Toolkit for cities – monitoring and reporting tools for cities and developing frameworks for action to aid cities at all stages during their efforts to green ICT.
- City support and action – a series of targeted exchange and learning activities (e.g. exchange on best practice examples).
- Outreach and engagement – a series of networking and visibility events to increase the number of Green Digital Charter signatories.

The toolkit is the main supporting mechanism for cities in the roll-out of their green digital activities. It provides an action framework, application guidance, and monitoring tools that are implemented as an online platform. This paper focuses the development of the action framework, the assessment and monitoring of activities and the concluding survey of signatory cities on progress and challenges of GDC implementation.

2. Methodology

As an EU FP7 "coordination and support action", the overall project methodology followed a transdisciplinary approach involving scientific and ICT expertise and in particular practitioners from the reference signatory cities in the co-creation and dissemination of knowledge and tools. The exchange and cooperation with the practitioners was implemented as an iterative dialogue through workshops, bilateral consultations and written feedback.

The project was concluded by a survey of signatory cities on progress and challenges of GDC implementation. The survey was conducted in a qualitative approach as a semi-structured telephone survey. Drawing on the EUROCITIES Database of ICT contact persons all 41 signatory cities (at the time of the survey) were contacted, 18 expert interviews could be derived of which 13 covered the full range of issues.

3. Results

3.1 Action framework

A core challenge at the beginning of the project was to extract, interpret and structure the detailed commitments and targets behind the political phrasing of the GDC for practical implementation [4]. From the charter text 102 commitments for different types of action were extracted, which aim at different types of objectives (e.g. strategic or practical implementation) and scales of relevance (e.g. city administration or city-to-city exchange). Based on this analysis of the commitments in the Charter, European policy, city initiatives and activities, as well as direct feedback from the NiCE Reference Cities Group an *"Action Framework"* was designed as a three dimensional matrix (Fig. 1). The dimensions of the action framework are:

1. The **application areas** for a city: Public Lighting, Green ICT, Energy, Buildings, and Transport. In addition, "Cross-domain" and "Other" application areas are considered to widen the scope.
2. The **type of activity** cities might undertake: Operational, Measurement, Exchange, Policies, and Governance.

3. The **roles that ICT** can play: Innovation / Substitution, Analysis / Decision support, Perception / Behaviour, and enabling Efficiency improvements.

The action framework provides a baseline document for all further work: At first, it helps local actors to get an overview of the overall action field and identify locally relevant starting points and approaches to action. Second, it provides the ontology and basic structure for the NiCE best practices and tools database and third it is a reference for monitoring progress.

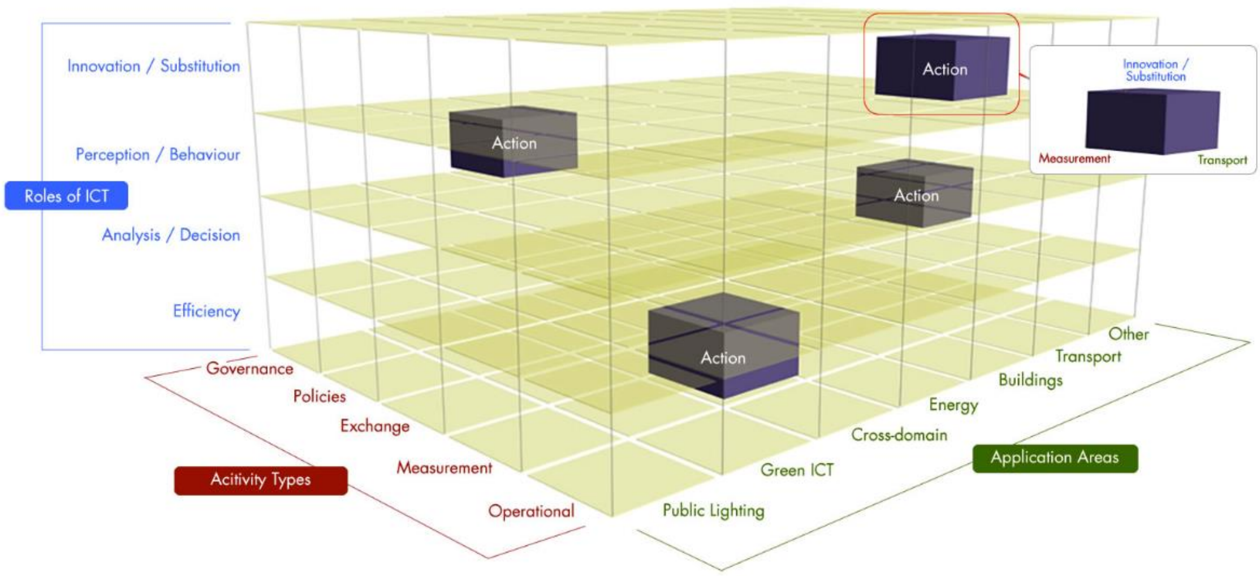

Fig. 1 NiCE GDC Action Framework [5]

3.2 Self-assessment and monitoring

„We signed the Green Digital Charter on Friday. What should we do on Monday?“ In fact, the Green Digital Charter provides a lot of ideas and starting points for Green Digital Activities. However, each city is different with respect to Green Digital progress achieved and options for further targeted initiatives. To this end and besides the action framework, the NiCE project also elaborated an analytical tool for cities to review their local situation and to support the identification of starting points for action. In a first attempt, the tool was set up as an indicator system that directly reflected the 102 commitments of the GDC. However, during the feedback process with the practitioners it became clear, that a comprehensive set of GDC indicators is not manageable in everyday practice. As a result, the broad variety of issues was then condensed into a consistent set of 26 “Self-Assessment Questions” (SAQ). Close cooperation with the NiCE partner cities (Reference City Group) assured that the final set of SAQ is at the same time meaningful and operable for practitioners in the cities.

The SAQ are organised along the activity types of the action framework and refer to all of the commitments of the GDC. The self-assessment tool is implemented online and allows cities to easily assess their current state on green digital activities, their strengths and weaknesses concerning their green digital development and to monitor progress. Along with the questions, the tool provides explanations, background information (e.g. linkage to the generic GDC commitment) and practical examples, providing starting points for action.

After completing all the 26 SAQ, the results are displayed as progress achieved in a percentage of GDC fulfilment for each activity type and as an overall result. As an element of benchmarking, the total progress result is compared to the average of the top ten cities. Finally a qualitative verbal feedback is given, that invites to browse the database of activities and tools, that is also implemented in the toolkit and populated by the participating cities (Fig. 2).

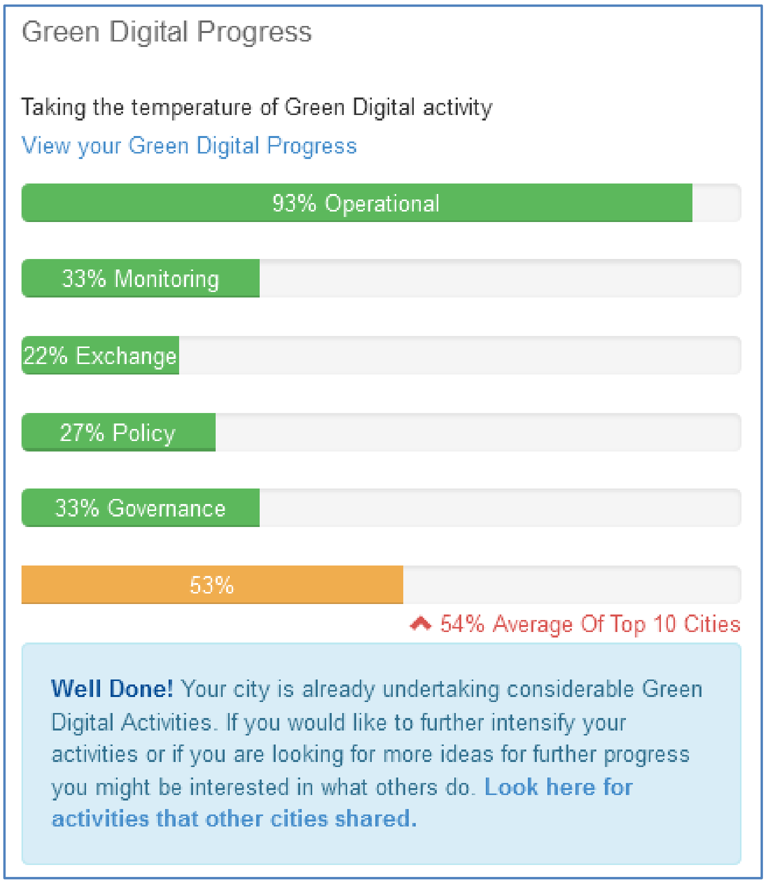

Fig. 2: Green digital activity self assessment feedback by activity type and compared to the benchmark of the Top 10 Cities (screenshot; content restricted to signatories)

Besides the self-assessment tool, two further tools are implemented; one to review the city's ICT carbon footprint and a second one to integrate GDC activities and the reporting on "Covenant of Mayors" activities, another important initiative for the implementation of urban sustainable energy policies. However, these two tools are beyond the scope of this paper.

3.3 GDC signatory cities survey

3.3.1 Green Digital dynamics:

Asked for an initial overall assessment, half of the respondents took a positive view on their green digital situation and described their situation as progressing well. Beyond that, two different general perspectives could be identified. On the one hand a merely political perspective, on the other hand an operational perspective. From a political perspective, the respondents referred to commitments and strategies like for example a digital agenda or an ICT strategy but also pointed out related low carbon programmes or roadmaps. In addition, the more general political context was mentioned, like a general aim of becoming a "smart city" or improving cross sectoral decision making to support an integrated consideration of environment and ICT related issues. From an operational perspective for example projects dealing with energy efficiency in buildings, smart grids, electro mobility, carbon footprint measuring and real time consumption monitoring for behavioural change were mentioned.

On the other hand, shortcomings were also mentioned. Several respondents described a “gap” between digital progress and other/general city development activities: *“The willingness is there but there could be better exchange between the different stakeholders”.* As a result, ICT application often appears more as a solution to particular problems but without a long term strategy.

With respect to green digital drivers and barriers, the respondents referred to quite different issues, such as economic and governance related issues, the local situation of environment and infrastructures as well as quality of life and city marketing. Main barriers were found in governance issues – in particular lack of communication and cooperation – and economic issues, such as shortage of budgets and subsequent limited human resources. Economic issues as drivers were spelled out into cost savings through the use of ICT and in general options e.g. for pilot applications provided by economic growth. The latter at the same time was reflected critical as resulting in a dependency of green digital progress from economic growth. A majority of respondents furthermore highlighted actor related and governance issues as drivers: “*Local stakeholders are the drivers to push ICT.*” Several respondents mentioned local programs to improve the environmental situation or the quality of life as supportive for green ICT, occasionally also related to marketing purposes: Towards the “*Green, save and smart city*.”

3.3.2 The Green Digital Charter – Trigger for Green Digital Action?

Looking at the relevance of the Green Digital Charter for green digital progress, the survey results generally provide no evidence, that the Green Digital Charter is a particular trigger for green digital action. This does not mean, however, that the Charter has had no impact at all. Nearly all respondents pointed out that, although not directly leading to new initiatives or projects, the GDC had a general stimulating influence on the wider green digital process and progress. In particular ICT practitioners consider the political commitment as supportive for ongoing projects and initiatives. Also the involvement into a network with other cities with similar interests was welcomed for exchange and learning but also fund raising purposes. At the same time, some respondents also pointed out, that there is a lot of action similar to the GDC commitment, which sometimes makes it difficult to handle the different involvements: *“There are so many places to network, to get information”.*

4. Conclusion

Summing up, the general impression from the co-operation with the practitioners and survey results is that the Green Digital Charter provides a lot of ideas, starting points and support for Green Digital activities and action. At the same time for many cities signing the charter seems to be first of all a political and symbolic act and only in very few cases backed up by a clear concept and an explicit strategy to systematically implement green digital progress. This conclusion is in line with one of the core results of the “Comparative Study of Smart Cities in Europe and China”: “Most smart city projects are actually addressing the implementation of individual solutions to individual problems identified in a community rather than comprehensive overhauls of the way cities are managed.” [6]

5. Acknowledgements

The results summarised in this paper have been developed by the team of the European NiCE FP7 funded coordination and support project [7] under the lead of EUROCITIES and in cooperation with practitioners from the GDC signatory cities. The major work in conducting and analysing the survey of signatory cities was performed by Sandra Wille, Leibniz Institute of Ecological Urban and Regional Development [8].

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Occupant discomfort due to background passive ventilation

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Summary

Background passive through-wall ventilation remains the standard for dwelling ventilation across much of Europe including in Ireland and UK. Shallow retrofit practice is focused on envelope insulation and boiler replacement. Natural ventilation is generally provided for through background wall vents and only intermittent mechanical fans installed in moisture heavy spaces such as bathrooms. This means of ventilation provisions requires review if we are to develop an efficient, comfortable, healthy housing stock. This paper uses a selection of social housing in Ireland that has undergone shallow retrofit as a basis. It assesses the impact of background ventilators on internal environments through an experimental and modeling assessment. There is a common occupant dislike for passive uncontrolled venting as it causes draughts, increased street and wind noise in the homes. Occupants often block vents to prevent draughts and noise, thereby undermining the home ventilation strategy and detrimentally affecting the provision of good indoor air quality. Experimental assessment exhibits varying air ingress velocity with varying external weather conditions. Computational fluid dynamic models show draft and temperature asymmetry that induce thermal discomfort in locations close to and under wall vents. The efficiency, and sustainability, of the building stock is compromised as energy consumption is increased to produce additional thermal energy required to condition the surplus volume of cooler outdoor air.

Keywords: passive ventilation, through-wall vent, occupant comfort, draught, Part F building regulations

1. Introduction

Passive through-wall ventilation remains the standard mode of purpose-provided ventilation in Ireland and the UK, and hence impacts the energy efficiency of a significant portion of the 1.5 and 26 million homes in each country respectively. Through-wall ventilation is listed as one of a few options in Irish and UK building regulations for means of ventilation in new builds, but is most popular given its low investment cost, and simple installation. In retrofit applications it is also the most common method of air change provision. Similar to the UK [1], grant incentives are generally provided for shallow retrofit and less frequently for deep retrofit, and hence this practice of ventillation will remain common in housingretrofit and new build. Alternative means of ventilation, including mechanical and hybrid means, are available and increasingly commonly specified in European countries. Home ventilation state-of-the-art systems use mechanical means enabled with heat recovery (MHRV), and with heat pumps for a holistic system. However, these systems are often prohibitively costly and cultural ties to occupant controlled and non-mechanicanised means of home ventilation are strong.

More advanced and designed means of passive ventilation are increasingly available. Ventive, a possible energy saving and comfort enhancing solution, can integrate passive ventilation with heat recovery, utilising stacks and cowls or ductwork reliant on buoyancy and wind forces [2]. Provision of ventilation using purely mechanical extract ventilation would rely on air ingress through inherent infiltration sources to balance the pressure difference. Although reliant on inherent air tightness limitations of the construction, such a solution would reduce localised draft and comfort asymmetry in occupied spaces, instead spreading air ingress across a wider range of smaller apertures and ensuring continuous ventilation. Demand control ventilation is proposed to offer a humidity controlled mechanical ventilation solution with cheaper captital cost than MHRV. Novel hybrid solutions [3] have been developed that provide airflow through natural driving forces, supported by mechanical exhaust fans at times of low natural driving forces.

However, as long as passive through-wall ventilation remains the standard in Ireland and the UK its impact on the comfort of occupants within the housing stock requires consideration. The occupant's sense of comfort, and more pertinently reaction to discomfort, defines the space heating energy loads in the home. The energy impact of passive through-wall ventilation in Irish homes has been shown to have a significant impact on both energy consumption and health conditions in the home [4]. Resulting ventilation rates can be almost double target rates, and result in up to a 45% increase in space heating energy load. Hence, a widescale strategy such as through-wall ventilation provision as part of a retrofit program, will affect the sustainability of the housing stock for decades to come. Revisions to the Part F Technical Guidance Documents [5] of the Irish building regulations which consider building ventilation and hence the means of good air quality provision have long been called for. This paper examines the response of occupants in terraced housing types common to Irish and UK cities and towns. It assesses the impact of passive through wall vents on occupant comfort through an experimental and simulation study. Risks of localised di comfort are highlighted in Irish conditions and alternatives to this practice are discussed.

2. Background

Passive ventilation may be provided for through a variety of means. Purge ventilation commonly refers to the opening of envelope opes to induce extensive air change and purge the building of stale air. In Irish and UK regulations purge methods are to be used in association with continuous background ventilation to ensure continuous adeqaute ventilation in the case of a passive ventilation strategy. Continuous background ventilation may be provided for using vertical stacks, trickle vents in window frames, or through-wall vents. This study is primarily concerned with the later which represents the most typical means of home passive ventilation in Ireland and the UK.

2.1 Through-wall ventilation

Through wall ventilation involves the total perforation of the external building envelope to enable air change with the outside. Abiding by building regulations Part F, can require an aperture of between up to 10,000m^2 depending on room and house size. Previous research has shown this practice to have significant negative impacts on the energy efficiency of buildings [3].

Fig. 1 Row of terraced housing with through wall vents visible on front facades of homes.

To enable a cross ventilation of the building wall vents are installed front and back with intermittant mechanical vents installed in locations of high moisture such as bathrooms, kitchens and utilities. Fig 2 shows a wall vent through a 300mm solid masonry block wall, without insulation.

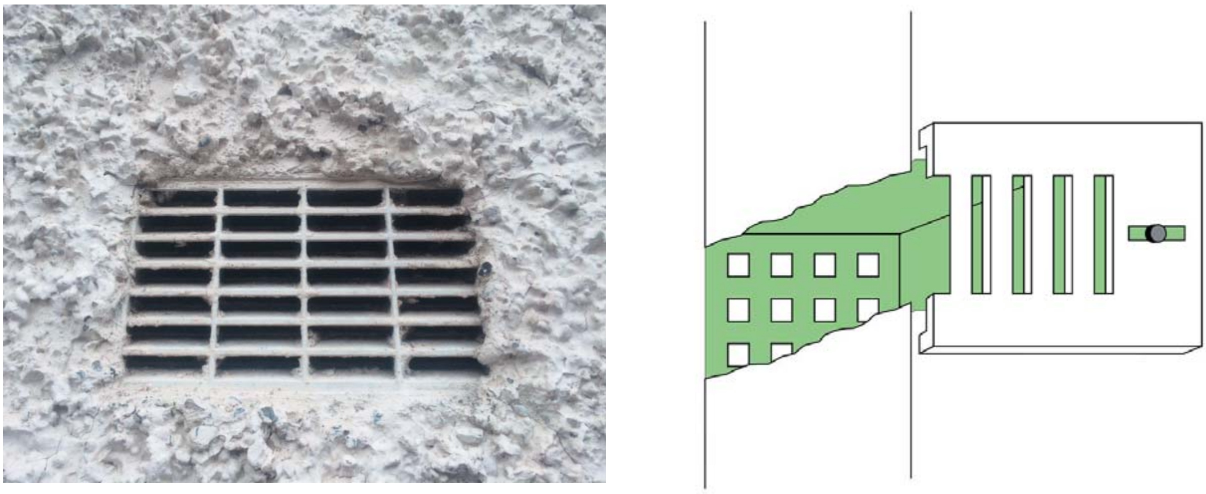

Fig. 2. External view of throughwall vent perforating the envelope (right) background ventilator as a through-wall vent in UK Part F documents [4].

1.1 Comfort

1.1.1 Occupant comfort

In similar Irish terraced housing to that being analysed in this study Sinnott [5] reports widespread expression of discomfort by building occupants due to the installation of passive, through-wall vents. Occupants report draughty homes, due to general poor air tightness but also as a result of passive through-wall vents installed post-retrofit [3]. The positioning of vents was particularly problematic. Occupants were impacted by cold air ingress in locations where living room seating and beds in bedrooms were situated below vents. A number of authors have highlighted the lack of understanding of the concepts of, and reason for, home ventilation [6][5]. Sinnott [5] reports that most occupants of houses in his sample set sealed vents using tape or other means. Occupants persisted with sealed vents even when condensation and mould growth were evident.

1.1.2 Quantifying comfort

The adaptive model of thermal comfort is a commonly accepted model by proponents of sense enhancing architecture, low energy buildings and increasingly by the facilities industry. This model dynamically links the comfort temperature to the monthly mean of the outdoor temperature [7] and by doing so removes the emphasis on tight heating control. It is approproate for naturally ventilated buildings, in which thermal conditions generally drift in a wider range around specified comfortable temperatures. Fanger's PMV model is an algebraic expression of the heat balance for the human body in the thermal environment. This approach to thermal comfort explains the response of occupants to their thermal environment in terms of the physics and physiology of heat transfer. It is based on an index of thermal comfort which expresses the thermal state of the human in terms of the thermal environment including allowances for air and surface temperatures, humidity, air movement, clothing and activity. This approach is often much maligned and strict adherence to it is claimed as responsible for increased energy consumption in buildings, that aim to design away thermal sensation [8]. it is however used in this study to assess localised differenciation of comfort within a room where substantial contrast exists.

2. Methodology

The purpose of this paper is to present an initial evaluation of the performance of terraced housing using a combination of monitoring and building simulation in the context of a post occupancy study which documented the reactions of occupants in these homes, after the introduction of through wall vents. Results are presented in the context of indoor environmental conditions primarily air flow and temperature, as well as thermal comfort assessment, evaluated using the PMV method.

2.1 Experimental Study

To assess air-flow through an example louvered vent an anemometer and temperature sensors are located within the living room of a sample terraced 80m^2 house. A hot wire anemometer is hung 80 mm from the vent surface as shown in Fig. 3. Hot-wire anemometers consist of short lengths of resistance wire, that are heated by a constant current and maintained at a constant temperatire. The hot-wire anemometer then measures the heat convected away from the wire by the passing air. Further temperature sensors are placed within the room to calculate room temperature. Data is averaged over 10 minute periods.

Fig. 3. Experimental setup of hot wire anemometer at 100mm from internal face of louvered vent.

2.2 Modelling Study

A model of the case study terraced house typology shown in Fig. 1 is developed. A case study house, of the investigated typology, is simulated for typical winter week. The IWEC Kilkenny, Ireland weather file [9] was used to obtain outdoor air temperature, pressure, wind speed, wind direction and humidity. The principle construction parameters and performance characteristics of the house are listed in **Error! Reference source not found.**. These properties are used to develop the construction model of the house for thermal energy analysis in DesignBuilder. Simulations are undertaken using EnergyPlus, through the graphical interface provided by DesignBuilder. The EnergyPlus platform is integrated with DesignBuilder using, for example, its construction, material, fabric and glazing data for modelling building heating, cooling, lighting, ventilating, and other energy flows. DesignBuilder also includes a simplified Computational Fluid Dynamic (CFD) application. CFD is commonly used to simulate air movements and temperature fields in ventilation applications. In room spatial comfort analysis is undertaken using PMV calculations spatially derived for environmental condition asymmetry in the room. Comfort measurements are taken at 0.1m, 0.6m, 1.1m and 1.7m as outlined in ISO 7726.

Element	Notes
Vent type	Through-wall. Louvered interior/exterior. Room vent area: 10,000 mm^2
Space heating	Central heating, radiator network. Heating setpoint: 21ºC.
House type	Two story end of terrace house, $80m^2$. Room dimenstions: 4m x 4m.
Wall construction	300mm solid concrete block wall with 25mm render.
External conditions	IWEC Kilkenny, Ireland weather file.

Table 1. Modelling parameters for CFD analysis study.

3. Results

3.1 Experimental results

In an ongoing study temperature and air velocity measurements are taken continuously over a period of a number of months. A single 12-hour period is presented in Fig. 4 and Fig. 5 which display the characteristic temperature difference between room and incoming air (Fig. 4), and also between steady and variable ingress air velocity (Fig. 5).

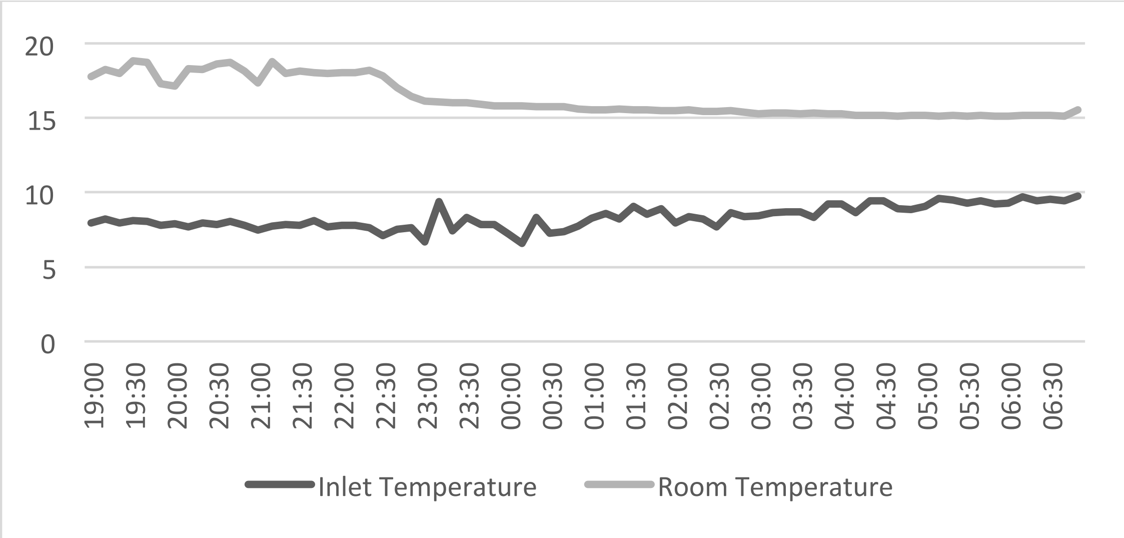

Fig. 4. Room and Inlet temperature (ºC) during 12 hour monitoring period.

Data is recorded during a period of unseasonally warm conditions for November. To date no whole house, central heating has been used. A single heat source, in the form of an open gas fire, is used to preheat the room to a temperature of 18ºC. The means of heating is maintained until 22.30 when the room is vacated and heat source is switched off. The room is allowed to cool through the night. A temperature difference of 5-10ºC is observed between incoming air and room temperature. Outdoor air temperature increases from 8 to 11 ºC in this time period.

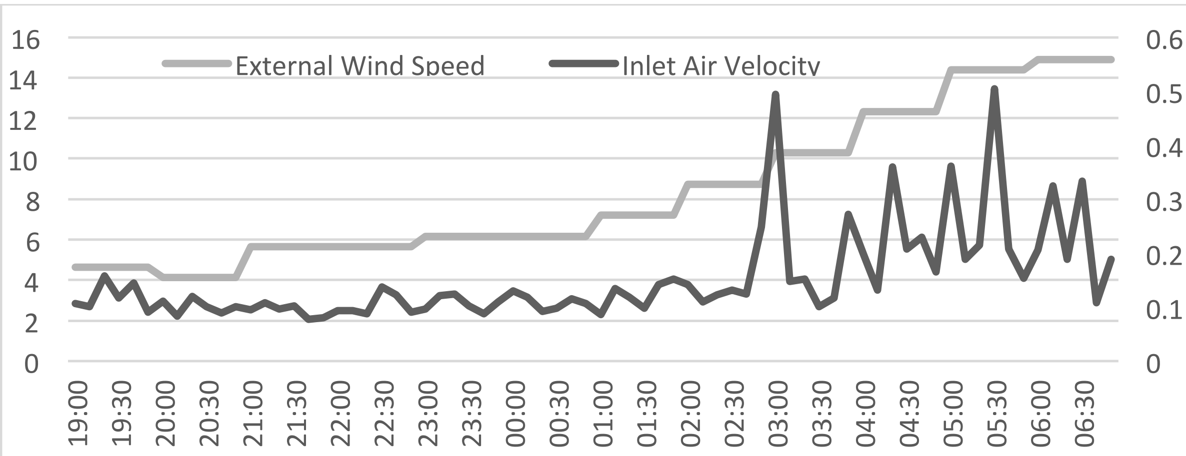

Fig. 5. Inlet air velocity and external wind speed (m/s) during 12 hour monitoring period.

Fig. 5 shows the real time air velocity in the room in the same 12-hour period. Inlet air remain generally constant at around 0.15 m/s in the evening and early part of the night. However, in the early hours of the morning external wind speeds increase from 10 to 30 knots (5m/s to 15m/s as shown in Fig. 5) and increased vent inlet air velocity is observed. Gust speeds of up to 2 m/s are observed, during the 12-hour period shown. A wind direction of 200 – 220 is constant through the displayed monitoring period, a 90º offset from the facing direction of the vent.

Fig. 5 exhibits the inherent uncontrollable nature of this means of passive ventilation, showing it to be highly dependent on external weather conditions. Ventilation of the space increases considerably as the night progresses although dramatic cooling is offset by a steady increase in external temperature.

3.2 Air Flow Simulation

A sample house is simulated for a typical winter week and air ingress speeds and internal temperatures are validated against experimentally monitored data. Simulated values are within the ranges observed during prolonged experimental measurement. CFD analysis is undertaken to assess the profile and impact of ingress air (Fig. 6).

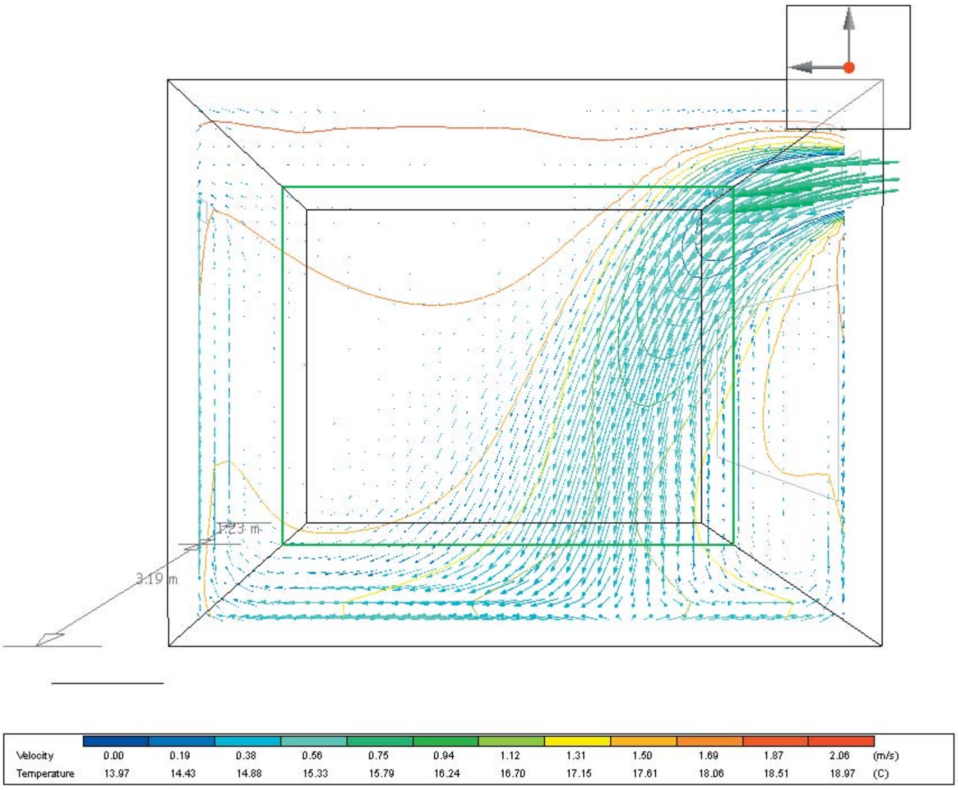

Fig. 6. Temperature and velocity slice profile of cold air dumping in the living room of a house containing passive through-wall vents.

Fig. 6 shows the heated living room of the simulated house with colder air ingress through a wall vent. The cold air drops from the entry height into occupied space; a phenomenom referred to as cold air dumping that can result in significant discomfort. This phenomenon was previously reported by these authors in post occupancy evaluation studies of mechanically ventilated spaces with forced high throughput [10][11]. Air movement adds significantly to the sense of discomfort with speeds of over 0.2 m/s creating discernable cooling effects. ASHRAE have long documented 'draft risk' zones as a balance of air velocity and temperature [12]. The highest draft risk is close to the floor where mean velocity is highest and the air temperature is lowest [13].

As shown in Fig. 6 the temperature variation within the vertical spatial range is impacted by the through-wall vent with greatest temperature assymetry close to the vents. Temperatures at the seating height are 2.5-3ºC lower than room temperature as a result of the incoming air. This differential is also evident at ankle (or close to floor) level where air is drawn under gaps in doors as part of the cross ventilation strategy outlined in Part F [2] of the regulations. In their seminal adaptive comfort paper in 2002, Nicol and Humpreys proposed that the range of temperate conditions which will be found acceptable at any one time is in the region of ±2 °C. In the case of passive through-wall ventilation temperatures the temperature range is observed to be as much as ±5°C in a single room in relatively mild winter conditions.

Comfort conditions, assessed using Fangers PMV as earlier outlined, are presented in Fig. 7. Considerable comfort asymmetry is evident. Comfort indices vary from neutrality in the region below high-level vents. Significant negative comfort indices (-4-to -9) are observed in the shown occupied area of the room. These findings support the claims of surveyed occupants in [5] who complain of significant discomfort in the seated area of their living rooms due to cold air falling from the through-wall vents installed at a high level on the wall behind their seating area.

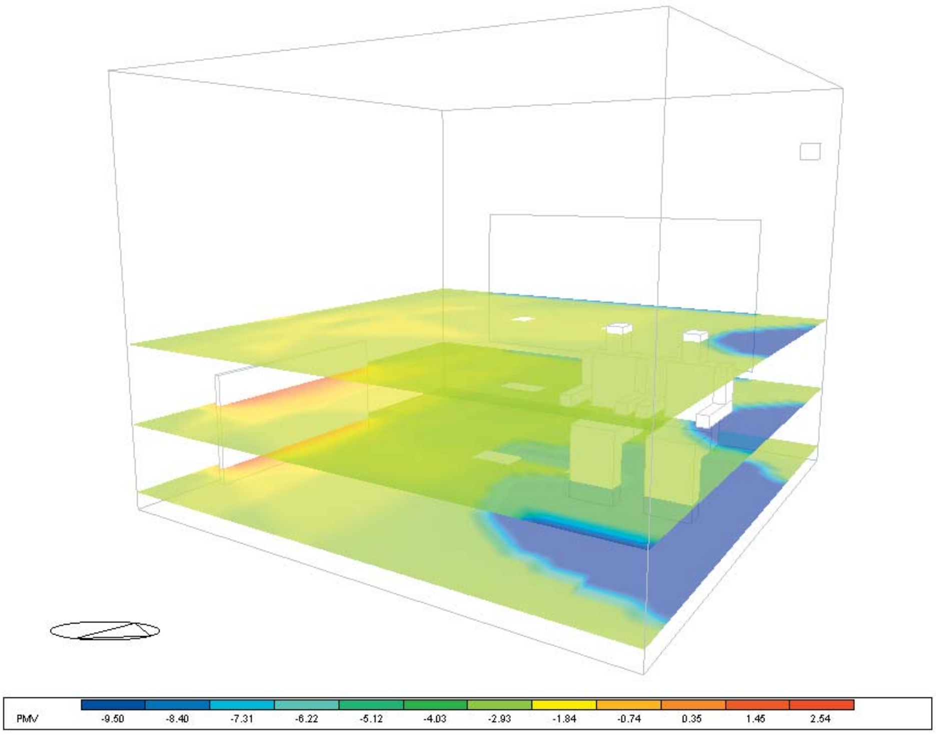

Fig. 8. Thermal comfort assessment using PMV slice profile in living room with high-level passive through-wall vents.

Simulations shown are undertaken with a southwesterly wind blowing directly on a southwesterly facing façade. When the wind direction varies, different conditions are observed including air exfiltration scenarios. When wind speeds are low, little to no air change is observed.

4. Discussion

This study investigates the current, and common, method of natural ventilation provision in Irish homes. It assesses the impact on occupant comfort of air change due to cold/unheated air ingress through wall vents. Specifically it analyses the findings of a post occupancy evaluation of homes in which through wall vents have been installed to meet Part F of the building regulations. As outlined in previous work the installation of passive wall vents in housing of this scale is commonly disliked by occupants who complain of high levels of thermal discomfort, draughts, and cold air dumping [5].

Revision of Irish ventilation regulations has long been called for by members of the ventilation industry who offer a range of alternative products [16] including some of the discussed. Technical guidelines are called for that stipulate designed ventilation solutions only, and do not prevent innovation and future adoption of alternative solutions. They should specify requirements for actual air movement in homes and means of testing and ensuring minimum standards. The future of passive ventilation in the context of climate change is uncertain. In recent work by these authors it has been shown that discomfort hours are high in climate change scenarios [17] and passively ventilated homes may be overheated for extensive periods. This is particularly a concern for elderly and vunerable occupants.

4.1 Limitations

DesignBuilder uses the EnergyPlus airflow network [18] that consists of a set of nodes linked by airflow components. It should be noted that this is a simplified airflow model compared to detailed models such as those used in complex airflow modeling such as CONTAM used by these authors in other studies [3]. PMV is effective and reliable in buildings including HVAC systems. However, field studies have shown PMV predicts a warmer thermal sensation than the occupants actually feel even when Fanger's expectancy factor is included [19].

5. Conclusion

Aims of passive ventilation provision and housing energy efficiency are proving difficult to reconcile. Without the means of heat-recovery, winter ventilation of dwellings ultimately results in heat loss and energy wastage, as warm indoor air is replaced by cold outdoor air. This practice is unsustainable. Also the current, and common, means of natural ventilation provision have the potential to set up significant conditions of discomfort in localised areas of Irish homes. Air ingressing through passive through-wall vents is at a significantly lower temperature than room temperature and incoming colder air can dump on occupants in the vicinity of vents. In small rooms, common to inner city housing this can have an amplified impact. The temperature range in small rooms can vary outside of guidance ranges proposed in the adaptive comfort models. This study validates the sensation of discomfort experienced by occupants in homes in which through wall vents have been installed. The adaptive action taken by these occupants to block vents, although creating a significant danger to health and wellbeing is understandable when considered in the context of thermal comfort. This study evaluates occupant response to ventilation provision in a limited set of homes in Ireland but can be generalised to a much wider range of European housing, including much of the UK. In other countries of Europe such as Germany MHRV is becoming increasingly specified. However, passive ventilation remains the standard in the current stock and the most appropriate means of provision continues to be a challenge, and affect the sustainability of the housing sector [20].

Passive ventilation allows for the experience of a living, breathing architecture. It has a range of benefits including occupant sensory and psychological enhancment. However, when provided for using through wall vents localised drafts result in zones of comfort asymmetry. Ultimately the sustainability of the building stock is compromised as energy consumption is increased to produce additional thermal energy required to condition the surplus volume of cooler outdoor air that ventilates the home.

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On your roofs – get set – green!

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Summary

Hamburg is the first German city to have developed a comprehensive green roof strategy, aiming to plant a total of 100 hectares of roof surface in the city in the coming decade, to deal with the challenges climate change, densification, biodiversity, and air quality. The strategy combines different policy instruments: incentives, public relations and regulation. The implementation process comprises an incentive programme about 3 Mill. Euro, combined with mandatory requirements and quality standards. A local communication campaign is to raise awareness and knowledge among important actors. In the context of the ongoing scientific support in the implementation of the strategy, the strategy is being assessed to identify success factors of- and barriers to the successful implementation. In the first, qualitative assessment it is found that the essence of the success of the green roof strategy lies in the comprehensive approach, with the three action points enhancing each other in a continuous process.

Keywords: Green roofs, Subsidies, Legal Framework, Communication, Science-Practice

1. Introduction

The city of Hamburg faces diverse challenges in the daily praxis of urban planning and development: climate change, densification, biodiversity and air quality are all important issues that have to be dealt with throughout the coming decades. Climate change not only requires the reduction of greenhouse gas emissions, it also requires new solutions to adapt to the effects of climate change. In a growing city with a limited building space, questions arise how the densification induced by the necessary housing programme can be combined with an upgrade of the quality of green- and recreational space, with care for the biodiversity in the city.

Green roofs provide an answer to these challenges, or a way to better deal with them. Besides the improvement of the urban water cycle by retention of rain water and subsequently evapotranspiration (Bengtsson et al. 2005; Mentens et al. 2006; VanWoert et al. 2005), there are additional benefits like reduction of heating and cooling costs and reduction of the urban heat island effect (Fang 2008; Takebayashi and Moriyama 2007; Nicholls et al. 2007), reduction of noise (van Renterghem and Botteldooren 2009) and air pollution (Currie and Bass 2008; Yang et al. 2008), biodiversity enhancement (Brenneisen 2003; Dunnett et al. 2008; Gedge and Kadas 2005) and (long-term) economic benefits (Berndtsson 2010).

Driven by these challenges, Olaf Scholz, the First Mayor of Hamburg, presented his vision of flying over Hamburg with a view over the green rooftops in 2030 at an international green roof conference in 2013 (see Figure 1). In due course, the Senate of Hamburg commissioned the city administration to develop a green roof strategy to realise this vision. The strategy was adopted in April 2014, formulating the aim to increase the green roof surface within the city by 100 hectares in the coming decade, to cover at least 70% of new buildings with green roofs and to make at least 20% accessible, for instance as public garden or rooftop terrace. Since then, the first actions were taken to put this strategy into action.

Fig. 1 Vision of green rooftops in the inner city
(c) BUE/TH Treibhaus Landschaftarchitektur, Background Image: Matthias Friedel

In this paper we present an assessment of the first experiences in the implementation of the strategy. Chapter two outlines the organisation of the implementation process and the actions taken to realise the aims. Chapter three presents the assessment of the first experiences in this process, from April 2014 until September 2015. The assessment is based on qualitative interviews with key players in the implementation. In a later stadium, this assessment will be complemented by a quantitative evaluation of the goals that are laid down in the strategy and a quantitative analysis of the reach of the instruments, e.g. by measuring the green roof surface, the amount of applications in the subsidy programme, the clicks on the website and the mentions in the press. The goal of the qualitative assessment is to define success factors and hurdles that can enable or hamper a widespread implementation of rooftop greening within Hamburg. Chapter four presents the first adjustments of the implementation process, which were made to overcome the hurdles. We conclude with the conclusions of the first assessment, identifying the main success factors in the implementation of the green roof strategy.

2. The implementation process

After the assignment by the Senate to develop a green roof strategy, the city administration at the federated state (*Bundesland*) level has taken up the challenge to create a strategy with a broad instrumental approach, covering the range of instruments that are available to the public sector: creating (financial) incentives and providing good examples, communicating about the positive aspects of green roofs and stipulating the greening of rooftops where necessary. These instruments were encapsulated into four action points, which will be further explained throughout the following paragraphs.

2.1 Action point 1: Promotion

The first action point comprises the promotion of rooftop greening through positive financial incentives and good examples. The main activity in this action point is the subsidy programme for voluntary rooftop greening measures by private and commercial land owners. Since January 2015, every private and commercial land owner in Hamburg can be financially supported if he or she decides to build a green roof. Although a green roof results in similar costs as a conventional flat roof, calculated over the entire lifespan of a green roof, the initial investment costs are higher. The subsidy encourages land owners to overcome the hurdle of the initial investment and to make a contribution to a more sustainable urban development and an increase in quality of life.

The Senate has made three million Euro available for the subsidy programme. The subsidy itself comprises a lump sum of 40% of the investment costs for green roofs on owner occupied houses (including outbuildings) with a net vegetation surface of 20-100 square metres. For larger measures and commercial buildings, the subsidy is defined by the net vegetation surface and the thickness of the substrate. Additionally, supplements are possible. The basic funding conditions and the possible supplements are summed up in Table 1.

Table 1: Basic funding conditions and supplements

Owner occupied houses (20-100 m² net vegetation surface (NVS))	All other buildings
Lump sum of 40% of the investment costs for the green roof and the maintenance in the first year	6,– €/m² NVS, plus 1,– €/m² NVS per centimetre substrate (max 50 cm) Maintenance in the first year (compulsory): 50% of the maintenance costs /m² NVS.
Supplements:	Supplements:
Statical improvements and improvements in root-resistancy on existing buildings (100%, max 5,– €/m² NVS)	Measures in the inner city (basic subsidy + 15%) The inner city is defined by the outer border of the second green ring within Hamburg's Green Network
Extensive green roof combined with solar panels (attachment of the solar panels, 100%, max 5,– €/m² solar panel)	Areas for recreational purposes (14,– €/m²)
Increased retention capacity (50 %, max 2,– €/m² NVS)	Statical improvements and improvements in root-resistancy on existing buildings (100%, max 5,– €/m² NVS) Extensive green roof combined with solar panels (attachment of the solar panels, 100%, max 5,– €/m² solar panel) Increased retention capacity (50 %, max 2,– €/m² NVS)

If we take a closer look at the funding conditions, we see that many of them are in line with the political goals that are laid down in the strategy. The dependency of the base funding on the thickness of the substrate is related to the goal of retaining as much rainwater as possible. Thicker substrates can store more rain water and thus contribute to a decreased pressure on the rainwater discharge systems. The supplement in the inner city is related to the special climatic conditions in dense urban areas. Rooftop greening is especially preferred in those areas that are known to develop into heat islands during summer and that are characterised by a high amount of sealed surfaces. The supplement for combining a green roof with solar panels is in line with the task of transforming to renewable energy and is an incentive to use the clear advantages of both measures and their synergies.

Another financial incentive to build a green roof was created by the introduction of the so called split waste water fee, dividing the original waste water fee into two parts, one for dirt water and one for rain water. Since the introduction of the split waste water fee, every land owner pays for the rain water that is being discharged from his or her property into the sewage system. The fee is calculated according to the amount of square metres sealed surface that is connected to the sewage system. If a land owner decides to build a green roof, he or she benefits from a reduced rain water fee by fifty percent for the roof surface, due to the water retention capacity of a green roof.

The city itself gives the right example by greening the rooftops of public buildings, like schools, universities and the premises of the city administration. These publicly owned green roofs are not only used as an example for other land owners in the city, but also to gain a better insight into the financial aspects of building and maintaining a green roof. Furthermore, on two locations, publicly owned green roofs are used in a real time measurement of the retention capacity of these roofs, as part of the action point scientific support.

2.2 Action point 2: Dialogue

The second action point comprises a broad dialogue with key players in the implementation of the green roof strategy. The dialogue is aimed at providing information about green roofs and communicating about the positive effects of rooftop greening within the city. Furthermore, the dialogue intends to discover and overcome hurdles towards a widespread implementation of green roofs. The approach within this action point can be divided into three separate elements: providing information, internal communication and external communication.

In order to create a uniform and coherent visual appearance in the communication in the course of the green roof strategy, a key visual and a style guide were developed. The key visual, with the slogan “On your roofs – get set –green!” and the image of a woman on a rooftop, carrying a vegetation blanket with the skyline of Hamburg in the background is the central element on the information material (See figure 2). The key visual appears on the cover of the brochure that was developed, as well as on the flyer, the poster and the standard digital presentation format. Furthermore, several visualisations were designed, to provide a positive image of the potential of green roofs in Hamburg and on the possibilities that a green roof provides (See figure 3).

Fig. 2 Key visual: on your roofs – get set – Green!
(c) BUE/mount. Design und Kommunikation für soziales Wachstum, Background Image: Michaela Stalter

The information material provides an overview of the positive aspects of a green roof and gives detailed insight into the range of possibilities of green roofs, from extensive sedum roofs towards intensive rooftop gardens. Furthermore, it provides information on the process of planning, building and maintaining a green roof, including information on the subsidy programme. Besides the already mentioned traditional hardcopy information material, the city has made a website to provide the information in a digital way as well (www.hamburg.de/gruendach). The standard information material is complemented by contributions in diverse media, such as journal articles, television interviews and newspaper articles, as well as presentations at conferences or trade fairs.

Fig. 3 Visualisation rooftop terrace
(c) BUE/TH Treibhaus Landschaftsarchitektur

The broad implementation of green roofs is not yet self-evident in Hamburg; there are several hurdles to be overcome, some of them within the city administration itself. Therefore, the dialogue in the internal communication process concentrates on providing information about the green roof strategy throughout the internal organization of the city administration. The responsibility for the implementation of the strategy is allocated within the department for environment and energy at the federated state level, whereas many other departments – at the federated state level as well as at the lower level of the boroughs (*Bezirke*) - make decisions that directly affect the actual realisation of green roofs. The dialogue within the internal organization is organised as a series of workshops and presentations, as well as support in concrete cases.

The external communication concentrates on building up a dialogue with key players in the planning, construction and maintenance of green roofs, such as private and commercial land owners, architects, building companies, housing companies, landscape architects and gardeners. The reach of the city is limited and the cooperation of these key players is needed to realise the ambitious goals. As such, the dialogue concentrates on conveying the positive aspects of green roofs, providing information on the subsidy programme, finding good examples from within the city and better understanding the hurdles towards a widespread implementation of green roofs. The external dialogue is organised as a series of workshops, presentations and individual conversations.

2.3 Action point 3: Stipulation

The action point stipulation concentrates on developing and implementing ways to enforce rooftop greening through the instruments of spatial planning and nature protection. Since the 1980’s it has already been common to make rooftop greening on flat roofs compulsory in new detailed development plans within Hamburg. There is however a larger potential to use the existing instruments; the activities in this action point concentrate on utilising these potentials.

The department for environment and energy at the federated state level works on the creation and implementation of a map on urban climate and ecosystems as part of the city wide landscape programme, which is part of the city’s comprehensive planning instruments. Climate change has not been considered yet in the currently valid landscape programme, the renewal of the landscape programme inter alia intends to define climate change as one of the essential challenges. The new map contains action points on urban heat islands and rain water management and shows areas within the city with explicit needs for action, with concrete measures to deal with these challenges of climate change adaptation. Green roofs are part of these measures.

Although the obligation to build green roofs is already quite common in new detailed development plans, there are still several challenges to be overcome. First, there is no standard yet for substrate thickness; every borough can freely decide which substrate thickness is laid down in the detailed development plan, resulting in a variation that ranges from eight to fifty centimetres. Second, there are large areas in the city that are regulated by large scale detailed plans that were adopted under an older legal framework, without the possibility to include rooftop greening. The task is therefore to find possibilities within the valid legal frameworks to overcome this hurdle. Third, the obligation to build green roofs is often the result of a negotiation in the context of the legal framework on nature protection, utilizing green roofs to reduce the impact on the natural values in the area under consideration. It would be interesting though if green roofs can also be recognised as compensatory measure, as this would create new incentives to build green roofs. To uncover these challenges and to find ways to deal with them, several working groups within the city administration have the task to explore the possibilities and to develop solutions.

2.4 Action point 4: Scientific support

The scientific support for the green roof strategy concentrates on quantifying the rain water retention capacity of green roofs under the local climatic conditions of Hamburg and on getting an overview of the worldwide scientific knowledge regarding water management on green roofs. Furthermore, this action point includes the assessment of the implementation of the green roof strategy in the other three action points, the first results of which are presented in this paper. As a starting point in the scientific support, a literature review of worldwide studies regarding water management and green roofs was carried out. The results of this review are the starting point for the real time measurement programme of the rooftop of the HafenCity University building. In the measurement programme that started in March 2015, the rainfall on the rooftop is compared to the runoff in the downspout. The difference between both values represents the retention capacity of the green roof. Ten similar measurement installations are to be installed on five different green roof systems with special techniques to retain more rain water, to compare different roof types.

The assessment of the implementation of the green roof strategy concentrates on finding the important lessons that should be learned from the implementation process. To assess the success factors within the strategy, qualitative interviews are being conducted with key players in the implementation process. The outcomes of the interviews are used to define the success factors and to uncover where other or new approaches or steering mechanisms are necessary to overcome hurdles that are discovered throughout the implementation process. In the next chapter we turn to the first and most prominent results of this assessment.

3. First experiences in the implementation process

3.1 Promotion

In the first assessment of the activities in the action point promotion, it becomes apparent that there has been a continuous interest in the subsidy programme. The programme itself is being administered by the *Hamburgische Investitions- und Förderbank*, a city-owned bank that administers all subsidy- and loan-programmes initiated by the Senate. In the course of the first months, over a hundred consultations took place and several concrete applications for the subsidy were handed in. Nevertheless, it is hard to say if the subsidy programme can already be defined as a success. Experience with other subsidy programmes shows that the initial phase of a programme usually needs some time before a larger sum of applications comes in. It was experienced though that the subsidy conditions were not attractive enough for smaller measures, for instance the greening of a bicycle shed or a garage. Furthermore, it became clear that there were some legal questions to be answered that were not specified enough in the subsidy conditions.

3.2 Dialogue

The assessment of the action point dialogue shows a more differentiated pattern. In the internal communication process, many workshops and presentations were organised to discuss the added value of the green roof strategy and the consequences for other departments at the federated state level and at the level of the boroughs. The most prominent issues that were discussed were the investment costs and the water retention capacity of green roofs. The installation costs for gravel roofs are estimated at about 10 €/m², whereas the installation costs for extensive green roofs range from 15 to 50 €/m² roof surface, depending on complexity of the roof, substrate thickness, producer, etcetera. In attempts to make the cost calculation more transparent, it became clear that there were many diverging assumptions, for instance about the necessity of including specific technical elements in the calculation and the necessity of including the costs of an extra week of scaffolding around the building.

In the first activities in the external communication, for instance with representatives from the housing industry, logistics and architects, the discussion often also circulated around the investment costs. More importantly, the discussion concentrated on the question who should carry the higher initial investment costs. It is legally not possible to provide a subsidy for measures that are already marked as obligatory in a detailed development plan. For the housing industry it would be more attractive to get a subsidy, whereas the question for the city administration is which instrument is most efficient to reach its goals. It also became clear that there are still doubts about the quality of green roofs and about potential negative impacts. Doubts were for instance raised about the impermeability for water and roots. These doubts have been reinforced, especially in Hamburg, by the media coverage of the "*Heidberg Villages*", a case where roof constructions were damaged by moist and fungi due to incorrect insulation construction. Although the problems with were not caused by the green roofs, the media coverage still made this connection. Another special example comes from a logistics company with an extensive green roof where the largest seagull colony of Hamburg (<1.500 breeding pairs) established. In this media-covered case the company is annoyed about pollution from seagulls and it serves as role model for companies with i.e. high demands on hygiene and cleanness to prevent higher installation costs of green roofs.

3.3 Stipulation

The first assessment of the action point stipulation has brought deeper insight into the possibilities and consequences of making green roofs obligatory through the instruments of spatial planning. Although only first steps were made in the stipulation process, one particular point of discussion became apparent: the potential conflict between solar panels and green roofs. In cases where a detailed development plan prescribes green roofs, the possibility of using the rooftop for solar energy panels is included as a potential alternative solution. In such cases, the green roof strategy envisages a combination of green roof and solar panels, as these solutions can easily be combined and because the cooling effect of a green roof increases the efficiency of the solar panel by around three to four percent. There are however examples of rooftops that are entirely covered with solar panels, positioned in a flat position instead of the traditional angled position. In such cases, the green roof would not be able to function due to the shade of the panels and the lack of rain water in the substrate. The challenge is thus to find a formulation in the detailed development plans that does not exclude solar energy, but that guarantees a fully functioning green roof in case solar panels are installed. Furthermore, it is important that such a formulation is also used in concrete cases, which requires knowledge about the potentials of combining green roofs and solar panels among the employees within the responsible departments in the boroughs.

4. Fine-tuning the green roof strategy

The results of the first assessment uncover several issues that need to be considered in the further implementation of the green roof strategy. Most of these issues have already been incorporated into adjustments of the actions within the action points. It is interesting to see that several issues that were uncovered within specific action points had to be dealt with in the activities within other action points. It is here where the synergies between the action points come to live and where the added value of a comprehensive and broad implementation strategy becomes apparent. In the action point promotion, we have uncovered two issues: the attractiveness of the subsidy programme for smaller measures and the legal questions that arose during the implementation. In order to deal with the first issue, the subsidy conditions were adjusted to better suit the special requirements for smaller measures. The lump sum of 40% of the investment costs for owner occupied buildings with a NVS of 20-100 m2 was introduced during this adjustment of the subsidy conditions. The second issue had to be dealt with in both the action point promotion and stipulation. It needed to be cleared under what circumstances a rooftop greening measure can be considered a voluntary measure and in which cases a legal obligation would imply a negative verdict on a subsidy application. This aspect also needed to be specified in order to be able to provide clear answers to the housing industry during the workshops in the action point dialogue, to explain clearly why an obligatory green roof cannot be subsidised. Moreover, due to the discussion on the building- and maintenance costs, it was decided to monitor these costs for the rooftops of public buildings. The results of this monitoring process will provide valuable insight into these costs and enable a factual discussion on the costs of a green roof over the entire lifespan.

In the action point dialogue, the intensive discussions during the workshops and the media-coverage have led to the recognition of more specific reservations towards green roofs. Many of these can be countered by providing more information. The brochure that was developed for instance provides a balanced over-view of the positive effects of green roofs and the possibilities land owners have. Furthermore, the information on the website was improved, to provide more specific answers on the most common reservations. Another specific issue that was dealt with in the action point dialogue stems from the work within the action point promotion. In order to provide the good example with green roofs on public buildings it was found that the largest potential on public buildings resides with the state agency that is responsible for building schools and its accompanying buildings. To increase the knowledge within this agency, a separate workshop was organised to discuss the steps that are needed to make green roofs standard on school buildings. This dialogue has inter alia lead to the funding of green roofs on several schools.

In the action point stipulation several questions were made more specific in order to be able to find answers to the issues that arose in the other action points. The working groups are still in this process, it is therefore too early to assess the progress within the existing working groups. To deal with the above mentioned issue of combining green roofs and solar panels, the department for environment and energy at the federated state level has supported the responsible persons within the internal organisation with the necessary information on the possibilities of combining green roofs and solar energy. Furthermore, the green roof strategy was included in an event on solar energy, to raise awareness for these possibilities in the solar energy industry.

5. Conclusions

The comprehensive character of the Hamburg green roof strategy is unique in Germany. The strategy raises national and international awareness, as the experiences in Hamburg can provide valuable lessons for other cities that have to deal with similar contemporary challenges. After assessing the implementation process during the first seventeen months, we argue that the comprehensiveness of the implementation process, covering a range of policy instruments is one of the main success factors in this process. The action points are mutually enhancing each other in a continuous process, creating a “carrot and sticks” approach. In many cases, as described in the assessment and fine-tuning of the strategy, the issues that arose in one action point could or should be dealt with in one of the other action points. This is amplified by the actuality of the challenges and the political will behind the strategy, making it possible to make the necessary resources within the responsible departments available.

In a next step, the results of the implementation process will be quantified in order to monitor the factual progress in the sense of square metres green roof within the city of Hamburg. With the help of quantitative data, the success factors within the action points can be better defined. For instance with the amount of square metres green roof that were built with the financial support of the subsidy programme or the square metres that were obligated in new detailed development plans. Before these quantitative data are available we can only speculate about the success factors within the action points. Based on the experiences in the implementation, we however argue that the workshops within the dialogue, especially with the representatives from the housing industry, logistics and architects are an important step towards a widespread implementation. The open dialogue enables to discuss the different possibilities, to exchange ideas and to overcome hurdles in the implementation. We therefore recommend other cities to at least create such an environment for a dialogue in order to bring their policies to deal with the actual challenges of climate change, densification, biodiversity and air quality a step further.

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Optimization of energy planning strategies in municipalities: Are community energy profiles the key to a higher implementation rate of renewable energies?

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Summary

Energy-efficiency and CO2 neutral energy provision will be a central task for urban development in the coming decades. Despite promising efforts to approach this at community scale, the implementation of renewable energies is still too slow to meet global GHG reduction goals. The paper evaluates the current status of community energy planning via a review of literature and practice. Main findings of the paper are that current community energy planning lacks a systematic approach, suffers from insufficient information, tools and resources. Thus, municipalities are often unable to take on a steering role in community energy planning. To overcome these barriers and guide municipalities in the pre-project phase a decision-support methodology, based on community energy profiles, is presented. The first application of the methodology enabled the municipality Elmshorn to build-up a cost-efficient and carbon neutral district heating grid. The case of Elmshorn shows the capacity as well as the potential for optimization of the methodology, which makes further development of the methodology into a semi-automatic tool necessary. The introduced tool could enable municipalities to take a more active role in community energy planning.

Keywords: Community energy planning, infrastructure and energy concepts, implementation of renewable energies, community energy profiles

1. Introduction

One of the biggest challenges in the coming decades for our society will be to transform cities into sustainable and resource-efficient spatial structures. About 40% of final energy consumption happens in buildings and up to 80% of this takes place in urban agglomerations [1]. Construction technologies enable the development of low-energy buildings. But the sole consideration of new buildings isn't sufficient. The integration of old and new buildings into interconnected systems, supplied by renewable energies, becomes a key task. This task has to be approached at community scale – rather than at the building or the city scale – which has advantages, and seems almost like a necessity. It is at the community scale that many technical synergies can be realized, promising scale effects be reached, and decision makers be mobilized to act in their common interest [2]. The implementation of energy strategies should be a task for municipalities and urban planning [3]. But implementation rates of renewable energy systems are currently unsufficient to meet global energy strategy goals [4]. Frontrunner projects rarely get multiplied [5]. The reasons are barriers among the knowledge on technologies and the urban planning practice [2]. Energy strategies at municipal level are too general and technocratic to be implemented on a community scale and qualitative factors are not sufficiently considered [6]. Community energy planning, driven by municipalities, can be divided into four phases: Preparation and orientation; model design and analysis; prioritization of measures and decision; and at last implementation and monitoring of the specific measures [7]. While there is many of tools for the technical last three phases, there are just a few tools for the first phase [8], which is about identification of tasks, preparation and settings goals for CECs; it is crucial for the whole process, because it defines the procedure and technological path [9]. Municipalities are able to reach national energy policy goals, scaled to a local level, if they have sufficient planning tools, guidance, and a systematic approach [5][10].

The aim of the study is to contribute to a systematic approach for energy planning at community scale with the introduction of a decision-support tool for the first planning phase. The results are both theoretical and applied in practice. To achieve this, the current status of community energy planning in north-western Europe was assessed, via a literature study and the review of Community Energy Concepts (CEC) to apprehend the common practice. Based on the found deficits in literature and practice – lack of systematic approach, insufficient information and resources in municipalities and unsuitable energy planning tools – a decision support methodology was developed. The basic approach is to add qualitative information to quantitative energy simulations: To account the fact, that every community has different local settings, Community Energy Profiles (CEP) were developed that express qualitative factors that have to be considered in relation to energy planning in this area. CEPs can map the different challenges for energy planning, such as stakeholder interests or buildings with heritage value and in this way supply the municipality with additional qualitative information on energy strategies. This enables municipalities, in combination with quantitative energy simulation tools, to develop tailor-made energy strategies, which have a higher chance of implementation.

The decision-support methodology got applied on a case study to test the CEP, which confirmed main findings from the literature review and assessment of CECs. Further, the CEPs helped the municipality to find a feasible energy strategy and initiate a comprehensive energy planning process. The methodology needs to be extended with an attached semi-automatic energy simulation tool. The first application of the methodology indicates the high significance of the study, because the municipality tried for several years to initiate an energy planning process for the community development project, but simply lacked an overview of the local energy potential, energy demand and knowledge on adequate planning strategies. Further, the addition of qualitative data via CEPs to quantitative and theoretical energy simulation is a new approach and might help to bridge the gap between energy strategies and the actual energy strategy implementation rate.

The remainder of this paper is structured as follows: After the methodology section, the paper is divided in two parts: Chapter 3 summarizes theoretical results, containing the analysis of literature, practice of CECs and a barrier analysis for successful community energy planning. Conclusive, the decision-support methodology based on CEPs is introduced in 3.4. The methodology got applied in practice, in a case study, which is described in chapter 4. Finally, the results and impacts of the application of the methodology are discussed in Chapter 5., which is supplemented with suggestions for future research on CEP, to develop the CEP-methodology into a planning tool.

2. Methodology

The study started in 2013 as master thesis project and continued after submission until 2015. The research process is divided into two phases: theoretical research based on grounded theory and application of the developed methodology in a case study, after the concept of action research. In **the first phase,** a review of community energy planning literature (3.1) and several CECs in north-western Europe were conducted (3.2). The publications were classified by spatial level, author and relevance for municipalities. This paper only contains a summary of main findings and most relevant publications – a detailed analysis can be found in [2]. The purpose of analyzing CECs was to assess common practice of community energy planning to contrast theoretical literature. The findings are the basis of a barrier analysis of successful community energy planning.

To avoid bias in the sample of CECs, well-known and random projects were selected to depict a wide spectrum of cases. Tasks, planning procedures and driving stakeholders were analyzed, to enable the development of narratives for each case as well as a a cross-case comparison [11]. The cases were assessed using a combination of qualitative research methods; mainly document study, but also interviews and observations. Publicly available strategic documents were gathered and recorded in a database for each project. The data was supplemented with further documents from non-municipal institutions, interviews and observations. The constant comparison between the cases, based on grounded theory proceeding [12], allowed the identification of patterns, which were assigned to categories that are related to technical, economic and organizational aspects of community energy planning. For each case weaknesses, strengths, barriers and opportunities to bypass these were tagged and summerized in memos, containing the case key information. The concluding barrier analysis of the current state of the art of community energy planning in theory and practice (see 3.3), set the frame for the outlined decision-support methodology that should facilitate to a more successful community energy planning by municipalities (see 3.4).

The second phase is founded on the previously conducted theoretical research. In an action research phase [13], the outlined decision-support methodology was tested on a brownfield development project. The author suggested a planning methodology, based on the outlined decision-support methodology, to the municipality and developed a CEC to supply the community solely with renewable energies. As external consultant, the author accompanied the process from generation of the technical energy concept until the decision about the implementation of the energy strategy from spring 2014 until autumn 2015. Data was collected with the method of active participant observation [14], which enabled the researcher to gain an in-depth understanding of the barriers within the case study, about stakeholder behavior, and the planning process until the final decision about the technical concept. At the same time, the municipality had access to expert knowledge and new planning methods that they were not aware of previously. Ultimatley, the assessment of the case study allowed the evaluation of the first time use of the decision-support methodology to identify need for optimization and further research.

3. Part I: Theory based results

3.1 Literature findings

The scientific discussion and energy planning practice has changed from pure building assessment and modelling to a wider scale, looking at communities and the interaction between city, building, energy systems and users. Still, community energy planning is a rather new approach [14]. Hence, little literature for municipalities got published. Available publications focus mainly on techno-economic concepts and only to a lesser extent on planning procedures. The same applies for energy planning tools, ranging from Excel spread sheets developed and used by municipal staff or private sector practitioners to complex urban energy system models developed and used by academic institutions. There are a lot of tools available for the more technical and detailed later phases in energy planning, but only a few for the initial phase of preparation of decisions [16]. Municipalities compiling CECs have to hire consultants or collect information from various sources.

There are 3 main studies summing up information on community energy planning, targeting at the development of tools for municipalities to link urban and energy planning to proactively plan energy-efficient communities. Case studies and other examples from the En:EffStadt program are published in [2] and give a overview about methods for community energy planning. With material from the IEA EBC Annex 51, a multi-lingual manual on energy planning got introduced, which is going further into detail and contains an energy concept advisor based on case studies [17]. The UrbanReNet project has a rather technical approach, by combining energy demand and potential of communities into community archetypes [18]; besides examples of application of the archetypes, the development of a planning tool was announced.

The 3 approaches are based on morphologic energy modelling [19], thus, they only serve as orientation for municipalities and can't replace detailed calculations with actual building data.But they are currently the only ones combining technical, legal, administrative and procedural aspects of community energy planning. Still, these guidelines are too complicated for municipalities; they only adress on how to develop a CEC, but not the implementation, which leaves them incomplete.

3.2. Findings from the community energy planning practice

The different methodological approaches of the 10 CECs can be divided into two categories (see Table 1 for an overview – full descriptions in [2]): Calculation of energy demand and potential in a community based on building aggregation (bottom-up) or community typologies (top-down). While the top-down approach is more userfriendly and faster (e.g D,H,I), the bottom-up approach allows the integration of actual measurements and is more detailed (e.g. A,B,E,F). Few concepts use measured data; most are based on assumptions, which can be critical for financing renovation projects if the actual energy consumption is overestimated because of prebound effects [19]. Content-related differences between energy concepts occur from the type: For new communities', municipalities generally have a direct influence on energy use via building regulations or land-use planning, which allow particular statements on building sizes, uses, the energy demand and timeframe for implementation. These concepts are rather simple, because of the generally low energy demand that only needs to be matched with a cost-efficient energy supply system. Still, a lot of the possibilities stay unutilized, thus suboptimal solutions with a lower share of renewable energies than achievable were suggested for implementation. Reasons are a lack of technical knowledge in municipalities, opposition from developers and the tendency to see energy planning as an add-on, which is done by utilities or has a lower priority and targets can in a later stage be loosened (e.g. C,F) . If the focus was on energy, it seems that other areas like urban design or user needs got neglected (e.g. D,G).

Table 1: Overview of analyzed Community Energy Concepts

#	Municipality	Community project	Type of community	Number of apartments	Year
A	Malmö / SWE	Ekostaden Augustenborg	Renovation	1.800	1998 – 2007
B	Egedal / DK	Stenløse-Syd	New	800	2004 – 2009
C	København / DK	Nordhavn	New	3.000	2011 – 2025
D	Meppel / NL	Nieuwveense Landen	New	2.100	2010 – 2035
E	Hamburg / GER	Bergedorf-Süd	Renovation	380	2013 – 2050
F	Hamburg / GER	Wilhelmsburg-Mitte	New	150	2007 – 2013
G	Heidelberg / GER	Bahnstadt	New	2.500	2008 – 2022
H	Belm / GER	EGQ Belm	Renovation	140	2011 – 2030
I	Marburg / GER	Biegenviertel / Nordstadt	Renovation	750	2011 – 2030
J	Karlsruhe / GER	Karlsruhe-Rintheim	Renovation	700	2008 – 2014

The analyzed CECs for existing communities were more complex: The determination of the energy demand was, except for the Scandinavian case, a major task and dealing with the replacement of existing infrastructure was for all concepts an economical challenge. The main issues remain stakeholders, which have to be convinced to adapt their individual actions towards a cooperative community target. The implementation of the energy strategies for existing communities is pending on stakeholder involvement, which is in all analyzed CECs a weak spot: The strategies stay vague, fragmented and short-sighted. Frequently, CECs stay techno-economic (e.g. E,H) and contain only drafted implementation strategies, which makes a realization questionable.

3.3. Barriers for a successful municipality driven community energy planning

Literature on community energy planning can be divided into two types: technically scientific publications, focused on specific problems in modelling or energy simulation and guidebooks or manuals that are based on experiences from practice. While the former are more theoretical and require a technical in-depth knowledge, the latter sum up and generalize energy technologies for supply and demand in relation to energy-efficient communities, enriched with results from previous CECs.

Despite finding similar patterns in the structure of all analysed CECs, the actual proceeding, suggested technologies and implementation strategies – if existing – seemed randomly chosen. The selection of technologies and planning methodology in the concepts is unsystematic, which can partly be explained by the missing literature. Further, all concepts were created by external consultants, leaving the crucial role of the facilitator to coordinate stakeholders and steer the extensive process to the municipality. Limited knowledge on energy at the planning entities often resulted in lower energy efficiency achievements, than technically possible and an overall decreased implementation rate; no concept got fully realized. Thus, two major mismatches were identified:

- CECs and the available literature are too technical and rarely consider qualitative factors that are crucial for implementation of energy strategies. Thus, there is a gap between literature, CECs and actual implementation
- Municipalities lack knowledge on energy planning and ensuing a guideline on choosing adequate planning procedures to implement technical concepts

3.4. Decision-support methodology with "Community Energy Profiles"

As a reaction to the found barriers, a decision-support methodology is introduced in order to help the municipalities in the pre-project phase to:

Step1: Identify possible community energy technology strategies and assess their impact on the energy performance of the community

Step 2: Connect the technical strategies with qualitative information of the community, allowing the choice of adequate planning procedures to implement suggested energy strategies.

If municipalities have a perception of which energy solutions are feasible in an early stage of a project, they are able to act pro-active and make decisions about a general planning proceeding. This has advantages, such as a more target-orientated way of working, exploration of all potentials in an early project stage leading to lower costs, robust solutions and the attainment of co-benefits, which is advantageous for contacting local stakeholders. This is in particular for community renovation projects of high value if municipalities can offer fitting standard energy solutions in the beginning of the dialogue with house owners. The function of the methodology can be described as a rough energy

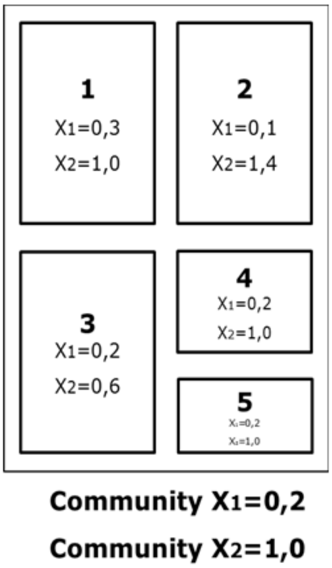

Fig. 1: Step1: Community built by 5 units with current energy production (x_1) and energy potential (x_2)

strategy feasibility analysis with an addition of soft factors to find the technology bundle that is most likely to be implemented and advice about possible planning strategies to achieve this.

'Step 1' of the methodology is to identify the current and future energy demand and energy potential from local renewable energy sources and find possible scenarios on how to match these. Every spatial unit within a community has three defining values: the energy demand; energy potential accessible via different technologies; and current use of the existing energy potential to meet the demand. If these three values interrelate into one value, the energy performance of a community gets measureable and comparable. The value is relative, because it originates from the current local situation and the local potential. Thus, if a municipality is assessing a community, it can measure to which extent the community or single units within the community can be supplied with renewable energy and how far the development is enroute to the target. Because of the lack of data in the pre-project phase, it is necessary to work with assumptions. For the energy demand, the use of building archetypes [22],[23] or urban block archetypes [18],[24] are necessary. The chosen approach is depending on the community size. For the energy potential it is possible to make assumptions for each energy technology based on values in relation to the area taken from various literature sources or from archetypes [18]. The most user-friendly way would be to use archetypes as a preset, which gets applied on each community energy demand and energy potential. The aim of 'Step 1' is to balance energy demand and supply from local, renewable sources and develop energy technology scenarios on how the community can be supplied with energy. A suggestion of three techno-economic most feasible solutions can be computed with the tool to show the municipality which basic options are available.

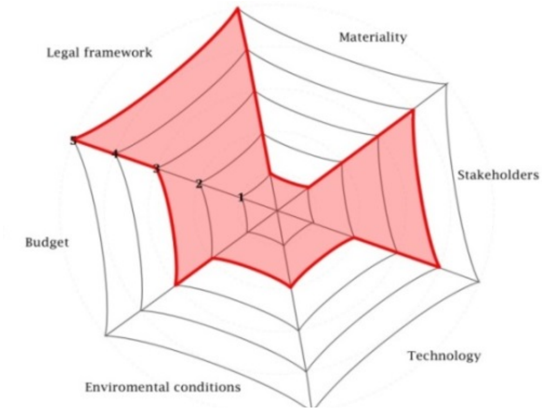

Fig. 2: CEP with challenges in legal framework and stakeholder involvment

'Step 2' of the methodology adds qualitative data to the quantitative energy technology scenarios. Community Energy Profiles should describe the complexity of different dimensions for each community. Through the division of community in different energy related dimensions – e.g. issues in the field of legal framework, technology, materiality, budget, stakeholders and environmental conditions – the complexity of communities can be broken down into different challenges (see figure 3). Through ascription of numeric values, detected for each dimension by 5 questions to be answered by the planner, districts get comparable via their challenges. This allows a comparison with earlier CECs. Hence, the meta information of case studies, the CEP that dictated the chosen planning strategy can be linked to the actual community. Thus, suggestions for successful energy planning methodologies can be transferred from communities that faced similar challenges in the past. The advantage with CEPs lies in the comparison of patterns instead of a comparison of unique local settings.

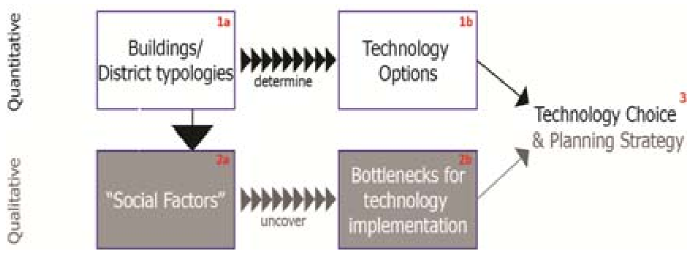

Fig. 3: Function of decision-support methodology

In this way municipalities get supplied with additional information, which enriches the energy technology scenarios and allows finding the main implementation barriers for each scenario. In case the energy scenarios from 'Step 1" are technically similar, the addition of a CEP shows which of these scenarios have a higher feasibility of implementation, determinated by the local setting in the community. With a library of CEPs from case studies, it is possible to suggest planning procedures to the municipality that have been successful in communities with similar CEPs, thus, with similar challenges and tasks. The knowledge about feasible technology strategies for their communities, the main barriers for implementation and an advice about possible planning methodologies can make the decision-support methodology into a valuable communication tool for municipalities to initiate community energy planning. The advantage of the methodology is that ‘Step 2’, the CEPs can stand alone and the energy strategy feasibility analysis can be performed by more advanced energy modelling tools, thus CEPs can still be used in a later project stage. Also it is possible to rescale municipal energy strategies with ‘Step 1’ to community level, which enables a continuos assessment of policy implementation.

4. Part II: Application results of methodology use in a case study

The in 3.4 introduced decision support methodology got applied in the municipality of Elmshorn for the first time. A more detailed description of the technical concept, cost-efficiency and feasibility can be found in [21].

Fig. 4: Investigated area (light coloured) with old building stock (grey), new developments (black) and waste heat sources (icon).

4.1 Investigated area

The community “Krückau-Vormstegen”, an 18.5 ha redevelopment area in the inner city of Elmshorn, is distinguished by a mix of abandoned industrial buildings, brownfields and occasional residential buildings. The municipality decided to redevelop Krückau-Vormstegen into a mixed use community as an extension of the inner-city. While some of the old industrial buildings with heritage value and the existing residential buildings, with approximately 210 apartments, should be kept; an additional 550 new apartments and around 60.000 sq. m. commercial and public buildings are expected to be realized until 2030. The typology is ranging from semi-detached houses up to huge warehouses. Neighboring, partly divided by streets, are several multi-story apartment buildings and two industrial sites. Further surroundings are small to medium sized commercial establishments and a train station.

4.2 ‘Step 1’: Technical consideration of energy demand, potential and energy strategies

Due to the new buildings and the bad condition of the old building stock, the future heating energy demand will change distinctly. After estimating the demand of the old building stock, energy renovation assumptions for all 35 old buildings were made, resulting in a heating energy saving potential of 51%; resulting in a total heating energy demand for the renovated buildings of 3.2 GWh/a. For the new buildings the heating energy demand ranges between 1.02 GWh/a (passive house standard) and 2.49 GWh/a (according to estimated building regulation energy standard). Together with the renovated building stock the communities overall heating energy demand ranges between 4.29 - 5.75 GWh/a. The overall electricity (EL) demand is estimated with 3.98 GWh/a.

The lack of reliable general key figures for local renewable energy potentials in relation to urban design made an individual consideration of all energy technologies for the local setting necessary. This was done by assessing the suitability of each technology in a process of elimination. If the local setting (climate, geology, hydrology, urban design and typology) doesn’t allow a technology, it wasn’t further considered. If a technology is suitable, its current technical efficiency was set in relation to available production capacity or available area to calculate the maximum technological energy potential for the whole community. The energy potentials can be found in table 2. It was found, that there is a total heating energy potential of 44.64 GWh/a and an electricity generation potential of 14.21 GWh/a theoretically accessible within the community. This surpasses the energy demand by far (see Table 2). In a second step a techno-economic feasibility analysis of seven energy supply variants was performed. Identified as most feasible energy scenarios were the use of a production waste from an industrial site next to the community that can be equated with biomass (A), a mix of solar thermal energy and heat pumps (B) or mix of industrial waste heat, heat pumps and roof integrated PV (C). All scenarios are based on the establishment of district heating. Scenario A, the use of local production waste, is distinguished by high cost-effectiveness.

Table 2: Suitability and technical potential of renewable energy technologies in the community

Energy source	End energy	Suitability	Energy Potential [GWh/a]
Industrial waste heat	Heat	Partly	1.73 – 3.46
Waste combustion	Heat/ EL	None	-
Drain water heat recovery	Heat	Little	-
CHP (oat peel waste, “biomass”)	Heat/ EL	Good	33.18 7.96 - 12.61
Geothermics , near-surface	Heat	Good	1 – 3.1
Geothermics, deep	Heat/EL	None	-
Photovoltaics	EL	Good	1.6
Solar thermal energy	Heat	Good	4.9
Hydropower	EL	None	-
Wind power	EL	Little	-

4.3 ‘Step 2’: CEP for Krückau-Vormstegen and the suggested planning methodologies

Based on interviews with local authorities, the utility works, business associations and landlords, the templates to develop a CEP for Krückau-Vormstegen were filled out by the author. Because of the parallelism of building renovation and new developments, the CEP for the community shows many barriers and tasks in all dimensions of energy planning. In particular the dialogue with stakeholders is crucial, first to access the waste heat and waste potential and second to reach the building owners and tenants for connection to district heating and building renovation. Further crucial points are the renovation of buildings with memorial status and the legal framework to supply the building stock with district heating. The technological barriers for implementation are rather small, because the suggested technical solutions are mainly standard. Specific barriers for the suggested energy scenarios were the different required temperature levels of the building heating systems (B,C), finding reliable stirling-engines in an adequate size (A) and to handle the varying waste heat accrual (C).

The suggested planning methodologies were retrieved from the assessed CECs from 3.2, for which CEPs were created. The main suggestions to the municipality were to take the leading role in a cross section working group between utility works, the industrial firm as possible vendor of waste heat and biomass, and the municipality. In a second step local building owners should be included. Further suggested measures are described in [2]. Concerning the reassessment of the energy scenarios the suggestion was made to drop option C and further investigate A and B.

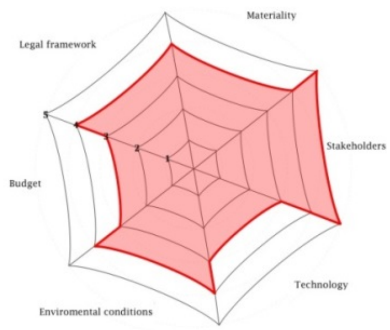

Fig. 5: CEP of Krückau-Vormstegen

4.4 Outcomes of using the decision-support methodology

After the use of the methodology and a presentation of the results to the city administration, an energy planning process was initiated. The basic decision to provide the necessary resources was made in February 2014 based on the results of the CEP; a stakeholder dialogue to check the general feasibility was executed, with the agreement on variant A or B as possible and beneficial for all stakeholders. The municipal parliament decided that the community should be supplied with an “innovative district heating grid”. In late 2014 an energy consultancy firm was hired to plan technical details, while the utility contacted landowners and developers in the community to discuss building renovation and district heating. Simultaneously, the municipality worked on a building energy renovation concept based on the suggestions of the CEP, which is still ongoing.

While the main landowners were convinced (owning 400 out of a total 760 apartments) to connect to a district heating, the implementation of variant A or B has not been reached yet: The variant A is endorsed by all stakeholders – because of technical difficulties with the CHP engines, as mentioned in the CEP, a central biogas CHP is the currently favoured variant. If adequate sterling engines are market-ready, the CHP unit and hence the fuel of the district grid could be changed. Status fall 2015, the community will get an open heating grid that can get gradually enlarged.

5. Discussion of results and conclusion

The results showed that it is possible to match the energy demand with local renewable energy sources in the community Krückau-Vormstegen. The suggestion of variants in connection to the next planning steps initiated a municipal energy planning process that was required for years. The difference to earlier attempts to bring up energy on the municipalities' agenda, were the availability of concrete and feasible options, systematic data on energy demand, and the knowledge about necesarry next steps. Another driver for the process was the possibility to implement a lighthouse project with the use of local production waste. It put energy on the political agenda and created discussions, which were unexisting before, because of lacking knowledge on energy planning and the expected high costs to buy external knowledge. These findings are correlating to the findings from literature and CEC practice. In the end, the municipality was more confident and target-orientated in acting and communication with local stakeholders, and commissioning energy consultancy. Thus, the use of decision-support methodology can be considered as successful because a self-sustaining community energy process was initiated. It is unlikely that the present most cost-efficient variant for energy supply via locally available biomass in the form of "production waste" can be found in the majority of similar local settings. Still, it shows the need for a detailed qualitative analysis of local renewable energy potentials apart from generic and purely quantitative assumptions. CEPs can only map the current state of a community, hence, they are static. To foster innovations they should become more dynamic. Thus, an integration of a time dimension would be necessary to be able to map technological progress, as seen in the case at hand, to avoid the implementation of solutions that in 5 years are already suboptimal.

The indicated process still is time-consuming and binds too many resources. Thus, automatic procedures and guidelines are needed, to enable municipalities to use the decision-support methodology to assess and optimize possible energy scenarios with CEPs. The next step is to refine the CEP methodology into a community energy planning tool, e.g. a stand-alone web tool that can be used with only minor data input. Concerning the data and models generating the scenarios, it should be considered to split the tool in two parts: One tool for urban and one for rural or suburban settings. Another possibility would be to split CEPs in new developed communities and renovation projects, because the latter are more complex and require more focus on planning procedures.

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Optimizing Low Carbon Retrofit Strategies in Residential Buildings from the point of Carbon Emission and Cost-effective

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Summary

This paper presents a simulation-based procedure to enable architects in residential building retrofit to predict and account for CO2 emissions and retrofit cost so that optimization selection of strategies could be made beforehand. Current performance of existing building is examined to diagnose the retrofit potential. Then low carbon retrofit measures are proposed. Next, CO2 emissions and retrofit cost of each option is quantified before and after retrofit by using DesignBuilder, Autodesk Ecotect and Microsoft Excel. These results are aim to help architects to determine the most recommended retrofit approach, and to save money for stakeholders.

Keywords: Residential Building; Retrofit Strategy; Low Carbon; Retrofit Cost; Simulation-based

1. Introduction

Limiting the average global surface temperature increase of 2°C over the pre-industrial average has become a global consensus. China has committed to reduce its carbon dioxide emissions per unit of GDP by 40 to 45 percent from 2005 levels (Copenhagen Summit 2009), and intends to achieve the peaking of CO2 emissions around 2030 (U.S.-China Joint Announcement on Climate Change 2014). Buildings are responsible for around 40% of global energy use, and generate up to 30% of global greenhouse gas emissions (World Green Building Council 2010). Residential building stock in urban area of China has exceeded 20 billion square meters and data shows that 52% was built before 2005, not up to current standard (Fig. 1). As the service life of building in China is 50 years, it is estimated that more than 95% will still be in use in 2030. It is therefore essential to retrofit the existing domestic building stock to improve their energy performance and to reduce their CO2 emissions in the face of global climate change.

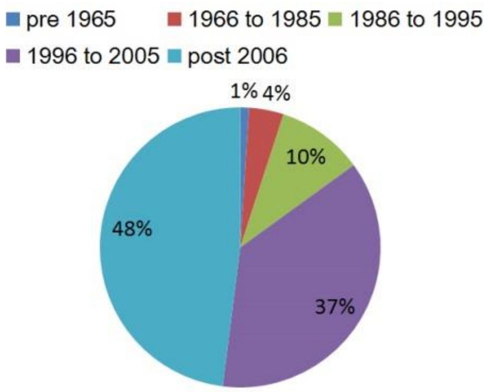

Fig. 1 Age breakdown of residential building in China Urban area (NBSC 2001, MHURDC 2005, NBSC 2012)

Through proper retrofit strategies, energy use and the resulting carbon emissions of the existing residential buildings can be reduced significantly. Since 1990s, China has taken a top-down approach to implement residence refurbishment, mainly focusing on energy-efficiency measures. Significant differences in terms of the implementation and scope of standard for energy efficiency of buildings, as well as the energy-saving targets were observed. The first national residence refurbishment standard set out requirements for the fabric and heating system renovation in severe cold and cold zones (JGJ 129-2000). Standards covering hot summer and cold winter zone (JGJ 134-2001) and hot summer and warm winter zone (JGJ 75-2003) came into force not long after that. Energy-saving target was set to 30% in 1980s, 50% in 1990s, 65% in 2010s comparing to the 1980s average level. According to the Ministry of Housing and Urban-Rural Development, the Green Building Act (2013) was passed which commits to accomplish 100% building area of residence refurbishment in severe cold and cold zones by the end of 2020.

However, residence refurbishment has always been defect-remedy oriented, and accordingly, measures were taken to improve energy-efficiency and living comfort, without much concern on carbon emission reduction. So, how to meet the national emission reduction targets is a problem. Lack of a proper method to select retrofit strategies and verify effectiveness, architects are observed to be absent from most renovation projects. What’s more, without much understanding of the cost and benefit of renovation, owners are lack of the initiative to retrofit. On the other hand, the Government is unable to differentiate between successful and failed projects, leading to problems when distribute financial subsidies. Furthermore, although reducing energy consumption is the main approach to reduce carbon emission, strategies share the same energy saving rate may differ in low-carbon effectiveness because of the variety of primary energy sources.

This paper presents a simulation-based procedure to enable architects in residential building retrofit to predict and account for CO2 emissions and retrofit cost so that optimization selection of strategies could be made beforehand. Current performance of existing building is examined to diagnose the retrofit potential. Then low carbon retrofit measures are proposed. Next, CO2 emissions and retrofit cost of each option is quantified before and after retrofit by using DesignBuilder, Autodesk Ecotect and Microsoft Excel. These results are aim to help architects to determine the most recommended retrofit approach, and to save money for stakeholders.

The purpose of this paper is to present the simulation-based procedure, which is expected to be replicable and affordable for a large scale application in the future. It intends to provide some reference to low-carbon domestic retrofit in China in relation to its attempts to identify the best approach available.

2. Methodology

At the early stage of a retrofit project, a set of investigations were conducted to gather information from the specific residence and to diagnose the retrofit potential. Then low carbon retrofit measures were proposed and form a list of groups. It is often necessary to verify the effectiveness of the options quickly and building simulation can be a helpful way to predict the performance optimization of each group. Unlike conventional defect-remedy retrofit which based on expert’s experience, given realistic information gathered from the specific building, modeling-based retrofit may guarantee more reliable results (Fig. 2).

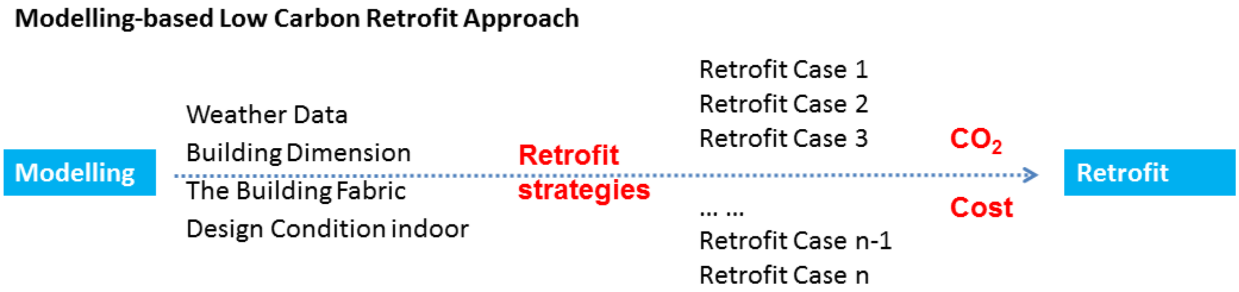

Fig. 2 Modelling-based retrofit framework

Information in relation with performance diagnose and modeling includes weather data, dimension and fabric of building, design condition indoor, which is required to be specific and realistic to ensure the accuracy of the simulation. At the stage, design standard for energy efficiency is utilized as a benchmark to find solutions for potential weakness. The standard provides an effective way to meet the energy-saving targets put forward by government.

Then low carbon retrofit measures were proposed such as fabric approach, system based approach, appliance approach and integrating renewable energy supply, depending on the climate and pre-retrofit condition. The retrofit strategies in this research are proposed based on severe cold and cold zones in China, where total heating energy of urban areas was 560 billion kWh, comprising 24% of building energy use in China (THUBERC, 2015). Among the retrofit strategies, fabric insulation could be quite efficient strategies for a previous poorly insulated project with clay brick wall and precast concrete roof which were commonly used for a 1980s residence. Uninsulated fabric may lead to massive heat loss due to wide temperature differential between indoor and outdoor in heating season. Household heat metering was suggested to be another retrofit measure as to central hot-water heating systems (MHURDC, 2011) for its effectiveness in promoting energy saving of user behavior. Household heating metering is most effective when thermal valves were installed on the hot-water radiators to provide separate zone control for individual homes or different areas of home.

Besides the strategies to reduce heating demand, attention has also been paid to decreasing electricity demand and meeting these demands through the application of renewable energy technologies. Most LED light lamps can save over 80% electricity compared to conventional incandescent lamps do (DoE, 2014), and could last longer with less maintenance. Abundant solar energy resources and appropriate climate provides condition for solar thermal panel installed on the each southern balcony to provide domestic hot water for adjacent kitchen and bathroom.

Measures were proposed and form a list of groups, such as elemental (for instance, external wall insulation), multiple (for instance, external wall insulation and roof insulation) and holistic approach. The software employed to calculate CO2 emissions and retrofit cost in the research included DesignBuilder, Autodesk Ecotect and Microsoft Excel. DesignBuilder is an advanced user interface to EnergyPlus, using EnergyPlus as its simulation engine. Due to its advantages of flexibility and ease of modification, it could be well suited for use in the stage of early sustainable design of buildings.

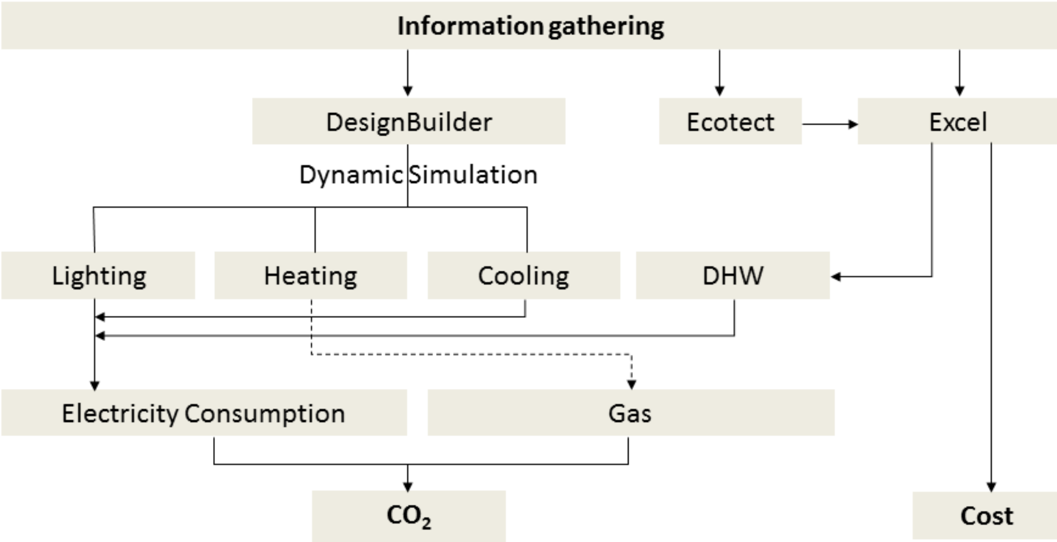

Fig. 3 Data flow process of software combination

Data were input to DesignBuilder to calculate the energy consumption to maintain specific indoor conditions. Domestic hot water demand was calculated by Microsoft Excel based on occupancy and appliance information gathered from specific building and referring to regulation in relation to this (GB 50555-2010). The solar thermal panel was then used to meet part of domestic hot water demand, and Autodesk Ecotect was utilized to model and estimate the energy generation of solar thermal. The total electricity consumption could be calculated by adding together these to supply the remaining domestic hot water and those to meet both cooling and lighting demand. The total gas consumption is equal to the heating demand.

The calculation of carbon emissions was based on operating energy data obtained above. For example, the potential carbon emissions could be got by multiplying the individual energy consumption with carbon dioxide emission factor (BRE, 2014). The bill valuation mode has been applied to calculate the retrofit cost by adding together cost of retrofit method employed.

$E_{oper,a} = E_{grid,a} + E_{fuel,a}$ (1)

$E_{grid,a} = U_{elec,a} \times EF_{gridOM}$ (2)

$E_{fuel,a} = \sum_{i=1}^{n} (U_{fuel,ai} \times EF_{fueli})$ (3)

$E_{oper,a}$ refers to annual operation emissions estimated, $E_{grid,a}$ refers to emissions from the use of electricity, $E_{fuel,a}$ refers to emissions from the use of energy sources other than electricity, $U_{elec,a}$ refers to annual consumption of electricity, EF_{gridOM} refers to carbon dioxide emission factor of grid, $U_{fuel,ai}$ refers to annual consumption of fuel i, EF_{fueli} refers to carbon dioxide emission factor of fuel i

$ReCost = \sum_{k=1}^{n'} ReCost_k$ (4)

$ReCost_k = A_k \times C_k$ (5)

ReCost refers to retrofit cost, $ReCost_k$ refers to cost of each measure, A_k refers to construction work quantity of each retrofit measure, Ck refers to comprehensive unit price of measure

3. Simulation conditions

3.1 Weather data

DesignBuilder and Autodesk Ecotect accept the most common weather data format EPW file by using EnergyPlus website.

3.2 Typical design condition indoor

Fig. 4 Typical design condition indoor

	Occupancy (all year)	heating schedule	set temperature	cooling schedule	set temperature	lighting LPD	Schedule (all year)
bedroom	0-7，100%； 7-8,50%； 8-9,25%； 9-22,0； 22-23,25%； 23-24,75%；	heating season start heating when less than	18℃	cooling season 0-9，100%； 9-20,0； 20-24,100%；	26℃	7W/m^2	0-7,0； 7-9,100%； 9-22,0； 22-23,20%； 23-24,0；
lounge	0-16,0； 16-18,50%； 18-22,100%； 22-23,70%； 23-24,0；	12℃		cooling season 0-14，0； 14-23,100%； 23-24,0；			0-16,0； 16-23,100%； 23-24,0；
kitchen	0-7,0； 7-10,100%； 10-19,0； 19-23,20%； 23-24,0；			cooling season 0-5，0； 5-10,100%； 10-17,0； 17-23,100%； 23-24,0；			0-7,0； 7-10,100%； 10-19,0； 19-23,100%； 23-24,0；
bathroom	0-7,0； 7-10,100%； 10-19,0； 19-23,20%； 23-24,0；			cooling season 0-5，0； 5-10,100%； 10-17,0； 17-23,100%； 23-24,0；			0-7,0； 7-10,100%； 10-19,0； 19-23,100%； 23-24,0；
Stair hall	0-9,0； 9-21,100%； 21-24,0；	no heating		no cooling			0-7,0； 7-24,100%；

1. Heating season: 15th Nov to the next year 15th Mar (GTC 2004), cooling season: 15th May to 15th Sep;
2. In order to estimate energy saving of user behavior brought by household heat metering and separate zone control valves, heating schedule was switched to accommodate user behavior, which means heating system would operate below capacity when the room was unoccupied;

3.3 Carbon dioxide emission factor

Fig. 5 Carbon dioxide emission factor

grid	1.058 Kg CO_2/ KWh (NDRC 2014)
gas	2.1622 Kg CO_2/ m^3 (NDRC 2011)

3.4 Comprehensive unit price of retrofit measures

Fig. 6 Comprehensive unit price

External wall insulation (65mm EPS)	18.88 $/m^2	Flat roof insulation (120mm XPS)	40.98 $/m^2
External wall coating	4.72 $/m^2	Heat meter	1560.42 $ per unit
Low-E double glazing	94.38 $/m^2	Thermostat valve	6.29 $ per unit
Window demolish	2.75 $/m^2	LED lamp	56.63 $ per unit
Flat roof finish coat demolish	2.07 $/m^2	Domestic solar water heater	1101.10 $ per unit

4. Case Study

By applying the methodology into a case study, the chapter demonstrates how this simulation-based procedure can be functional to assist low-carbon retrofit, especially in guiding to select strategies during early design stage.

4.1 Performance diagnose

The retrofit project is located in Tianjin, part of severe cold and cold zones in northern China. It is a 1980s 45-unit residential building. Before simulation was carried out, the following information had been collected (Fig. 7).

Fig. 7 Basic Information

Location	Tianjin, China	
Type	A 1980s , uninsulated, 45-unit, 5-storey residence	
Project stage	Occupied	
Floor area	2711.75 m^2	
System	Heating	Central hot-water radiator heating system
	Cooling	Split air conditioner
	Lighting	T2 fluorescent lamp
	DHW	Electric water heater
Fuel	Electric from grid and Natural gas	

According to fabric diagnosis (Fig. 8), external wall construction, flat roof construction and window of the case can't meet the benchmark (CHURDT 2013).

Fig. 8 Fabric diagnosis

	Actual Building	Benchmark	Attained
Shape Coefficient	0.31	0.33	☑
External wall construction	Solid Clay Brick 360mm, U-value=1.57W/ m^2.k	U-value≤ 0.4W/ m^2.k	☒
Flat roof construction	Concrete, Reinforced 120mm, Fly ash ceramics, 30mm, U-value=2.63 W/ m^2.k	U-value≤ 0.25 W/ m^2.k	☒

Window		Single clear (6mm) windows, U-value=5.84 W/ m^2.k	U-value≤ 2.3 W/ m^2.k	☒
Window to wall ratio	S	0.34	0.3~0.7	☑
	N	0.27	≤0.4	☑
	E	0.06	≤0.45	☑
	W	0.06	≤0.45	☑

4.2 Retrofit strategies and simulation cases

Based on pre-retrofit information and performance diagnose, low carbon retrofit measures are proposed for the case and form a list of groups, such as elemental, multiple and holistic approach. CO2 emissions and retrofit cost of each group is quantified before and after retrofit and these results are aim to help architects determine the recommended retrofit approach.

Fig. 9 Simulation cases

Base case (before retrofit)		
Retrofit cases (63 cases)	Elemental approach	① External wall insulation (65mm EPS) ② Flat roof insulation (120mm XPS) ③ Low-E double glazing ④ Household heat metering and separate zone control valves ⑤ LED lighting ⑥ Solar water heater for DHW
	Multiple approach	①+②, ①+③, ①+④, ①+⑤, ①+⑥, ②+③, ②+④, ②+⑤, ②+⑥… …②+③+④+⑤+⑥, sum to 56 cases
	Holistic approach	①+②+③+④+⑤+⑥

4.3 Results

Figure 10 shows the CO2 reduction rate and retrofit cost of 63 retrofit cases. It can be seen that the CO2 reduction rate increases as the retrofit cost goes up. As indicated by the case study, carbon reduction follows the law of diminishing returns. Architects may put forward the recommended retrofit approach based on the amount of money owners can pay.

On condition that retrofit cost is below 50,000$, Elemental approach ⑥ can achieve a carbon reduction rate of 37%; if the retrofit cost is between 50,000$ and 100,000$, multiple approach ②+⑤+⑥ can achieve a carbon reduction rate of 53%; when the retrofit cost is between 100,000$ and 150,000$, multiple approach ①+②+⑤+⑥ can achieve a carbon reduction rate of 60%; assuming the retrofit cost is between 150,000$ and 200,000$, multiple approach ①+②+③+⑤+⑥ can achieve a carbon reduction rate of 66%; with a high retrofit cost of more than 220,000$, holistic approach achieve a carbon reduction rate of 67%, only slightly higher than multiple approach ①+②+③+⑤+⑥.

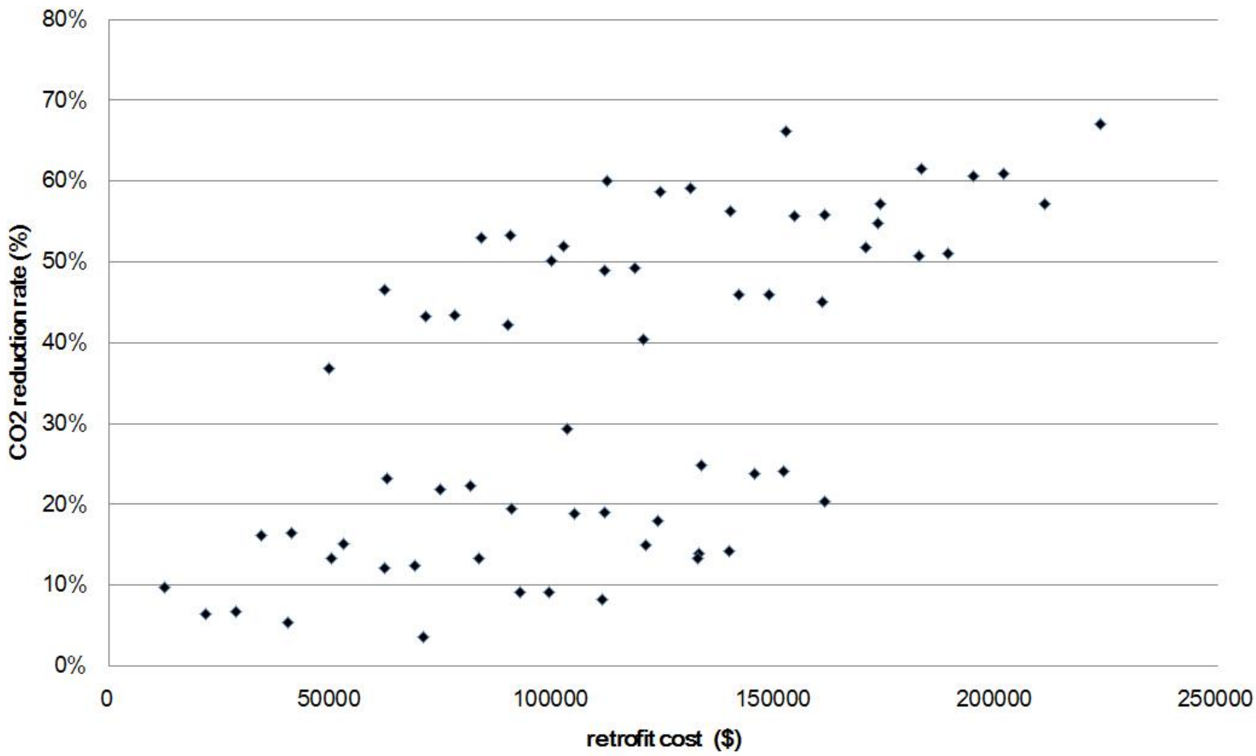

Fig. 10 CO2 reduction rate and retrofit cost of 63 simulation cases

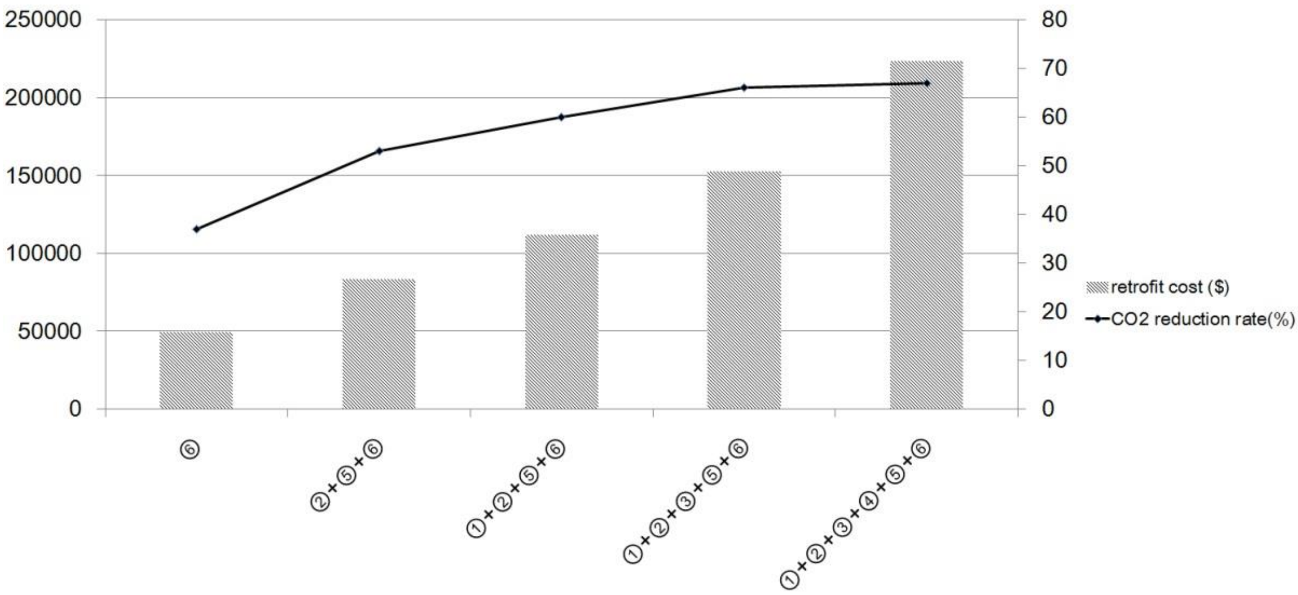

Fig. 11 A comparison of CO2 reduction rate and retrofit cost of different cases

So, if the retrofit cost was without limits, multiple approach ①+②+③+⑤+⑥ was the recommended case for the project, with fabric insulation including external wall, flat roof and window, LED lighting and solar water heater for DHW.

5. Discussion and Conclusion

Based on simulation results, with retrofit cost of 152,700$, multiple approach ①+②+③+⑤+⑥ should save 68% of electricity demand, 60% of gas demand, 63% of total energy use, and corresponding 66% of CO2 emissions comparing with the base case (Fig. 13). Passive design strategies like fabric insulation may guarantee the energy saving target of local government's standard.

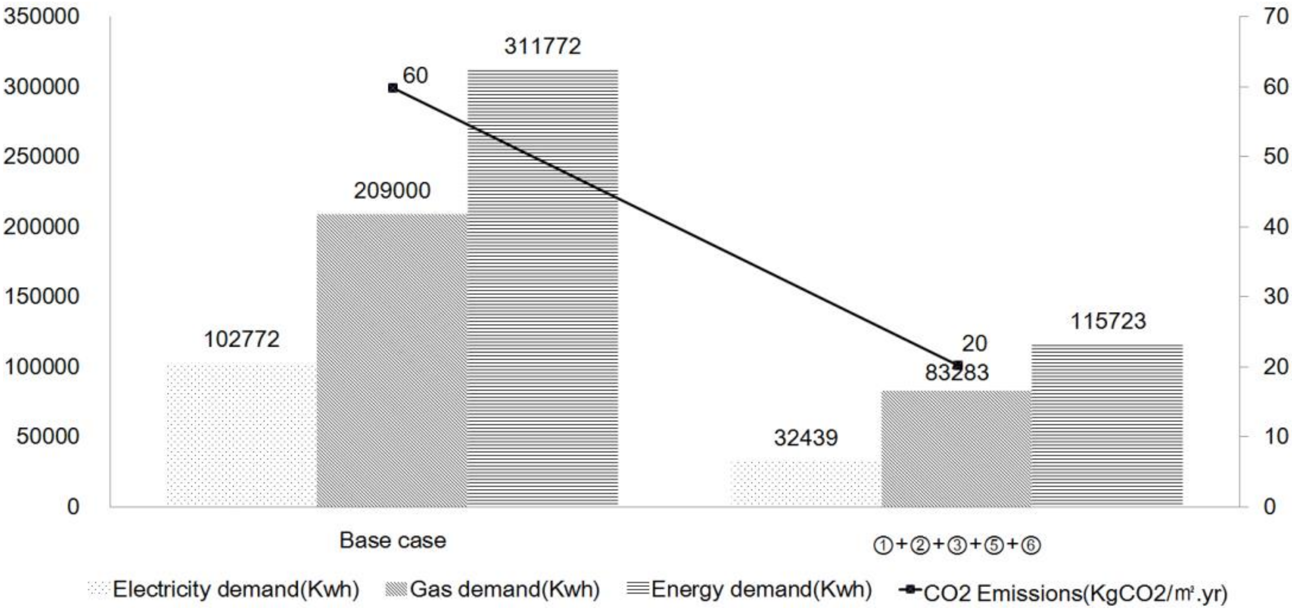

Fig. 13 Energy savings and CO_2 reduction of multiple approach ①+②+③+⑤+⑥

Above all, conclusions can be made as follows: renewable energy technologies and fabric approach could greatly optimize the energy demand and reduce CO_2 emissions of a poor insulated house with a conventional system.

In Tianjin, charging of the domestic central heating system has long been based on floor area of each home, other than measured heating load, although the government made great effort to implement heat metering and charging (GTC 2004). So the saving of money during operation is not included in the paper for the absence of reliable price of central heating system. Furthermore, as the paper is research oriented, the proposed retrofit strategies have not been implemented, therefore the real, measured energy consumption will not be covered in this paper.

By using the proposed simulation-based retrofit method, the objectives of optimizing low carbon retrofit strategies can be achieved. The function provides the architect and owner with a chance to guide the design and approve effective retrofit measures, and help to achieve the carbon reduction targets.

China has a huge residential building stock of 20 billion square meters, and attentions paid to low carbon retrofit are far from enough. In order to achieve the objective of carbon reduction in buildings, low carbon design must be applied at design stage. Optimization of low carbon measures can bring both high reduction rates and affordable cost.

Along with local foundation database being gradually optimized, life cycle assessment will be taken into consideration during further work in order to improve the accuracy of research.

6. Acknowledgements

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Planning of ecologically and economic optimized district refurbishments

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Keywords: District, refurbishment, life cycle assessment, life cycle costing, tool

Summary

Facing the refurbishment backlog in Germany's building stock and supporting sustainable development, a district lifecycle tool for refurbishment planning was developed to facilitate the consideration of ecological and economic aspects in early refurbishment planning phase. As the tool is intended to be used by decision-makers and planners on district level, the application requires no further measurement effort. Nevertheless, relevant aspects of sustainable buildings, namely Life Cycle Assessment and Life Cycle Costing issues, can be integrated in refurbishment planning to identify measures that are both economic and ecologically beneficial.

The refurbishment potential is calculated based on typological data from component level up to districtwide energy supply solutions. The level of refurbishment quality is delineated through several refurbishment scenarios facilitating an optimization based on energy, ecology or economy on building level. Thus, potentially beneficial combinations and the added value of districtwide measures can be identified. This includes the dimensioning of heat generation systems such as cogeneration plants based on optimization algorithms to maximize environmental or economic saving potentials. To show the results at a glance an eco-portfolio is presented including direct comparison of ecological and economic efficiency of the scenarios.

To further validate the tool, a case study has been carried out based on the refurbishment of the district of Karlsruhe Rintheim that was/is executed by Volkswohnung GmbH. For seven types of residential buildings refurbishment scenarios have been modelled and evaluated. Based on this the district refurbishment is assessed regarding both building specific improvements and the implementation of a district heating network including an optimized cogeneration plant. The present methodology successfully shows that saving potentials of district refurbishments in terms of economic and ecological efficiency can be predicted solely based on data already available in initial project stages. This facilitates the integration of ecological considerations from the beginning, allowing to identify districts of promising saving potentials at the beginning. Further optimization potentials are identified in terms of an enhanced implementation of user behavior. Within the next steps, the tool will be expanded to cover non-residential buildings such as educational institutions and commercial buildings as well.

1. Introduction

The provision of built environment forms an elementary prerequisite for a functioning society. In the context of globalization and the inherently increasing number of people with growing needs, the impacts of this element on environment and society are unmistakable. This applies to both the direct consequences of resource demand as well as energy needs for the conditioning of the built environment. Thus, with the right to housing being a human right, a further increase in demand for housing and habitat and associated environmental impacts is almost inevitable. In the context of this area of tension, the concept sustainable development offers a solution approach that provides a synthesis to overcome the seemingly insuperable contradictions.

To make this mission statement applicable on an everyday basis, the complex and elaborate concepts offered by science have to be put into practice. This applies, among others, for the principle of life cycle thinking, as the increase of efficiency within the use phase often comes along with an increased environmental impact of the production and the End-of-Life. Although the method of Life Cycle Assessment (LCA) includes these aspects and is widely accepted, its application often is too expensive or only used as ex-post assessment.

The tool described in this paper offers a solution to tackle the implementation barriers for life cycle based decision support, taking eco-efficiency aspects into consideration for district refurbishment planning. It facilitates decision support in terms of eco-efficiency predictions based on low-threshold data requirements. After describing the underlying methodology, a case study is presented to validate the tool and to identify its potentials as well as its limits.

2. Methodology

For the assessment of eco-efficiency potentials for refurbishments on district scale a multistage methodology was created by means of a combination of various existing methods and tools. The architectural structure of the methodology and the according tool is depicted in Fig. 1. It basically aims at quickly identifying saving potentials in order to give decision support on which district could potentially be subject of a district refurbishment without requiring the effort that usually is necessary for the estimation of economic of ecological saving potentials. Therefore, the minimum data required is available in any case. This simplification is enabled by the utilization of typological as well as generic datasets. The reduction of the prediction precision in saving potential is, among others, subject of this work. While the precision usually increases with the project progressing and the according additional data availability, the effort of the assessment increases as well. Furthermore, the more details are already defined, the less flexible the project gets. For decision support in terms of eco-efficiency it is thus beneficial to give information as early as possible. Therefore, further simplification of the methodology and resulting deviations from the applied standards are inevitable due to the low user-side effort required. These include inter alia the LCA methodology, that is simplified by means of the recommendations given in “EeBGuide”[1]. The user input forms the basic description of the system, which is then supplemented by typology data. As the user can provide data on a higher level of detail, the result will be more specific accordingly. To take the different system structures of buildings and districts into consideration, the methodology is realized through a double-stage system. First, the user can complete the assessment on building level, optimizing each building separately and creating the elements of the district as such. On district level the user can then assess the complete system regarding synergy effects and local energy supply.

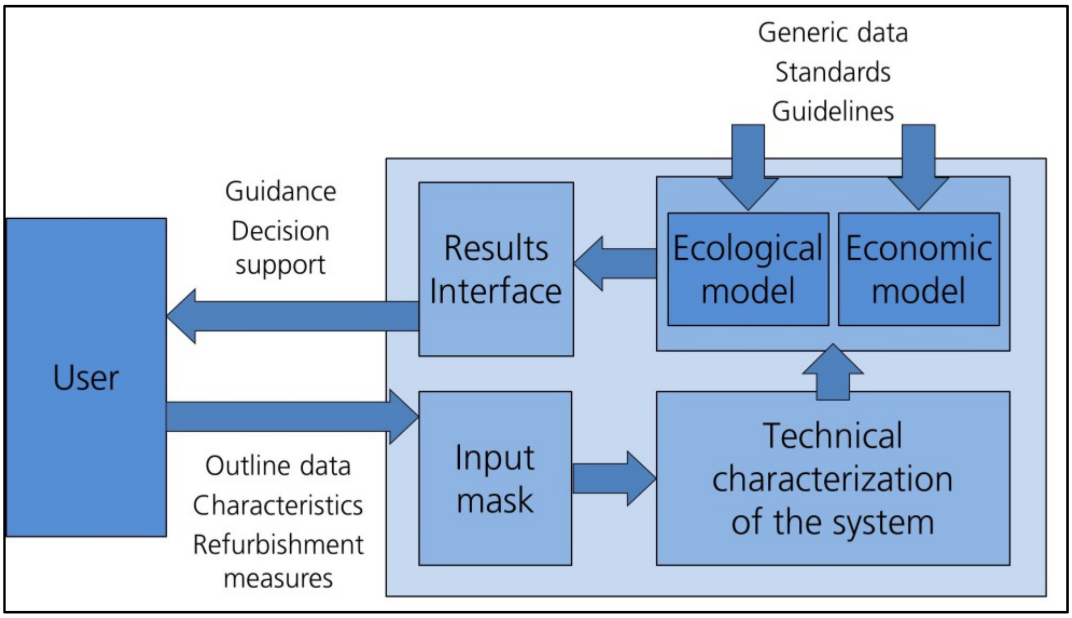

Fig. 1 Methodological structure of the applied tool

The addressed system basically consists of a residential district, meaning a gathering of mainly residential buildings within a spatially enclosed area. The system is restricted to the physical building structures as well as the infrastructure that is required for thermal as well as electrical energy distribution on district level. Furthermore, the assessment is solely addressing a comparison of different refurbishment concepts. The different refurbishment concepts are regarded as being comparable in system boundary and function. Thus, the building stock itself, any non-energy-related repair or modernization measures and transport as well as the implementation process are not included in the assessment. Although these restrictions in system comprehensiveness are not compliant to most extensive environmental assessments, they are strongly reducing the amount of required data without any reduction on concept comparability. However, this leads to the fact that the results acquired through this proceeding are not fully comparable to other assessments that usually include non-energy-related measures as well and aim at a complete assessment rather than a pure comparison. [1, 2]

The amount of data necessary to define the systems on building level has been reduced to the minimum. To define the building stock, the building type has to be specified and the year of construction as well as the floor space has to be estimated. However, to describe the system on building level adequately, a number of further aspects are recommended. These cover the heat supply system including ventilation and hot drinking water, average electricity and heat consumption and partial refurbishment measures already conducted including the year of implementation. If more elaborate data is available, information on component level can be specified as well. Based on these data the technical characterization of the building is conducted through combination of the foreground information given by the practitioner and background data based on German building stock typology. When the framework data is specified, the building is modelled for several refurbishment scenarios, covering a reference scenario only including maintenance aspects based on minimum legal requirements as well as refurbishments using state of the art measures or innovative measures. Again, the scenarios can be adjusted flexibly by the practitioner if desired. The refurbishment measures are specified based on “TABULA”[3], where frequently applied refurbishment measures are described specifically for all common residential building types in German building stock.

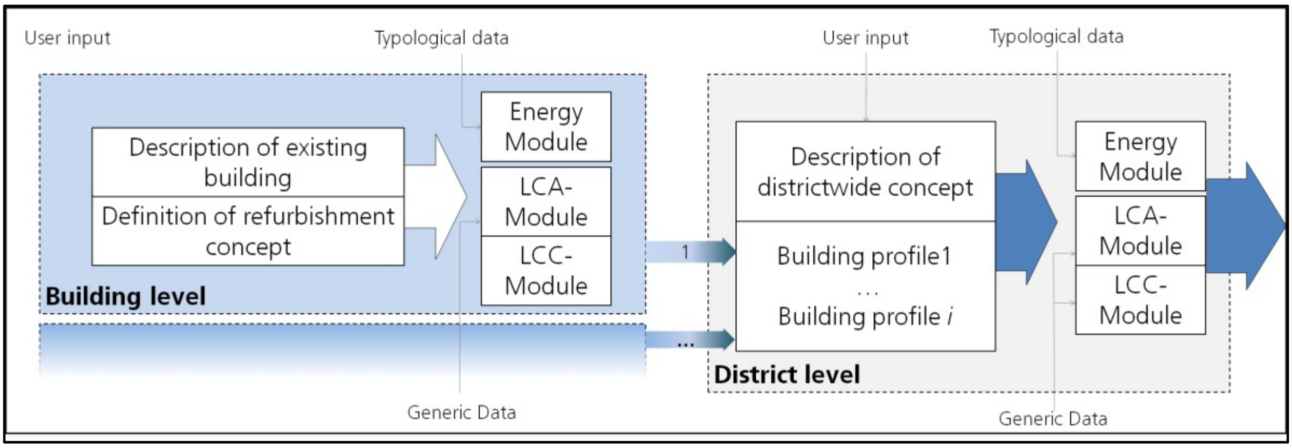

Fig. 2 Applied Modelling structure and required data sources

The modules required for the assessment of saving potentials on district level and their interconnectivity are shown in Fig. 2. As described above, the building specification and according modelling of energetic, environmental and economic saving potentials are performed first. The generated building models are then transferred on district level, where they are supplemented by the districtwide concept description including information on building distribution and information on energy supply systems if applied.

2.1 Energy Module

The energetic performance evaluation of the buildings is carried out as described in [4] using the quasi stationary calculation method based on floating monthly average temperatures. As this calculation requires information on geometry and energetic performance of all components of the building as well as efficiency information for energy supply systems, these data are either directly specified through the practitioner or estimated through the information on building type and construction year using the typological data given by “TABULA”[3]. As the implementation of photovoltaic elements is not included in this database, an additional module to estimate photovoltaic yield is added [5].
The energetic performance of the energy demand based on physical properties often overestimates the thermal energy consumption, especially if older, uninsulated buildings are to be assessed. Furthermore, the energy demand of highly isolated buildings is often underestimated, as users are not behaving as assumed for standard conditions especially in terms of window ventilation and room temperature [6]. As this is mainly induced by user behavior, the calculated energy demand based on physical properties is corrected through energy consumption information. If available, consumption data based on energy carrier demand can be used for the building stock. Otherwise, empirically estimated factors are applied to correct the calculated energy demand [3]. Thus it is possible to gather practical information to estimate the saving consumption based on plausible data, including specific data if available.

2.2 LCA Module

The assessment of environmental impacts through LCA has been subject to scientific research for several decades, resulting in comprehensive set of standards defining procedure and boundary conditions as well as quality levels [7–9]. Within this methodology, potential impacts on the environment that occur along the whole life cycle of a product are assessed quantitatively. For the building sector, these general rules are complemented by specific standards for both buildings and building products [2, 10, 11] taking building specific requirements into consideration. As these standards are not fully compliant and often require further information to unambiguously define the

action steps, a comprehensive guidance document called EeBGuide was developed on European scale to provide harmonized guidance for practitioners [1]. The calculation method applied within this work is derived from the screening assessment described within EeBGuide.
To assess the environmental impacts of refurbishment measures, data on energetic performance within building use phase has to be complemented by data on the impacts occurring within other life cycle phases. As a direct comparison of refurbishment scenarios is performed, these data is only necessary for replaced components. However, for building products that are required for the planned refurbishments, detailed data on production phase, predicted lifetime and End-of-Life phase have to be included. For building products, these information is given in Environmental Product Declarations (EPD) for specific products [2]. Furthermore, generic data is available in the database Ökobau.dat [12]. Particularly due to the screening character of the assessment, a simplified structure is chosen to only address the relevant issues. This again is valid for the definitions of the goal and scope within LCA. To facilitate an easy access to the environmental impact assessment results, the chosen impact categories are additionally depicted as single point indicator. This indicator takes the environmental relevance of the specific impact categories into account through the means of a weighting based on experts judgements. Detailed information on the applied LCA approach as well as on further complementary data can be found in [13].

2.3 LCC Module

In consistency with the environmental assessment, the economic potentials are assessed using a life cycle approach called Life Cycle Costing (LCC). However, in contrast to LCA, no general methodology has yet prevailed on a general level. Thus the methodology is derived from the building specific standard on economic sustainability assessment [14]. As economic saving potentials are strongly influenced by dynamic financial framework conditions such as predicted inflation rates and interest rates, these data have to be specified by the practitioner taking into account the case specific framework conditions. Data on predicted costs of construction measures are given by generic data that is flexibilized by means of building size and insulation thickness [15–18]. The cost development of energy carriers is estimated by recent and past cost structures, taking into account the range of cost predictions for concurrent scenarios [19]. Predicted system costs are then calculated according to VDI 2067-1 [20] on an annual basis. In addition to the construction and energy carrier costs public subsidies can be included in the economic saving potential estimation. As the methodology is focusing on application in Germany, the subsidies by the Kreditanstalt für Wiederaufbau (KfW) and the Bundesamt für Wirtschaft und Ausfuhrkontrolle (BAFA) are included [21].

2.4 District assessment

On district level, the same framework conditions and modelling structures as on building level apply. However, they are complemented by information on district typology and potential districtwide measures. Based on this information, the structure of district heating networks and resulting information on material and energy efficiency can be estimated. [22–24]
As far as energy demand and distribution of the district can be estimated, it is possible to calculate the dimensioning of the heat sources that can serve as district heating devices. The procedure is exemplarily shown on the dimensioning of a combined heat and power plant (chp), and can be based on several premises chosen by the practitioner. Under consideration of technical features as well as economic and ecological aspects, an optimization algorithm is implemented to estimate the ideal plant size and configuration either based on maximum thermal coverage rate, minimum environmental impact or maximum economic savings. For this estimation, the annual heating demand Q_{th} (in [MW]) and its seasonal distribution as well as the sum of installed boiler output and the simultaneity factor is required on demand side. Furthermore, the chp plant has to be specified

by its thermal and electrical efficiency and output as well as investment and maintenance costs [25]. To estimate the chp plant performance P_{el}, the following correlations on chp coefficient σ and nominal capacity P_{nom} are used [25].

$$\sigma = \frac{P_{el}}{Q_{th}} = \begin{cases} 0{,}5 + \frac{0{,}035}{100} \times Q_{th}, & | \; Q_{th} < 1\ MW_{th} \\ 0{,}85, & | \; Q_{th} \geq 1\ MW_{th} \end{cases} \qquad [-] \qquad (1)$$

$$P_{nom} = \frac{1{,}107 \times (1 + \sigma) \times Q_{th}}{\begin{cases} 0{,}81 + \frac{0{,}006}{100} \times Q_{th}, & | \; Q_{th} < 1\ MW_{th} \\ 0{,}87, & | \; Q_{th} \geq 1\ MW_{th} \end{cases}} \qquad [kW] \qquad (2)$$

To facilitate decision making support on district level, the results are depicted in an eco-portfolio, where ecological and economic savings are shown in direct comparison. Both ecological and economic savings are depicted in relation to the reference scenario, where no energy related measures are assumed either on building or on district level. Additionally, the results on building level are depicted in form of a point cluster, indicating the deviation within the district as well.

3. Case Study – refurbishment of the district Rintheim

To validate the methodology in terms of the robustness of predicted saving potentials, a case study was chosen where refurbishment measures on district level have been implemented and resulting savings have been assessed based on consumption. The refurbishment of the district Karlsruhe Rintheim fulfills all prerequisites and has therefore been chosen as case study. The district has been subject to a comprehensive refurbishment on district level including the implementation of a district heating system powered by a chp plant. To observe the refurbishment results, the energy performance was accompanied through several research projects within the project “EnEff:Stadt” covering the complete refurbishment process and its outcomes [26–28].

The district “Rintheimer Feld” in Karlsruhe is a residential urban district mainly consisting of high rise buildings and apartment buildings from the 1970ies, being heated by gas boilers and having a quite homogenous componential structure. Within the refurbishment, the district has been completely refurbished and the heat distribution was changed to a district heating system. Within the scientific accompanying research detailed simulations and calculations have been performed to identify reasonable measures and an overall integrative refurbishment. However, as the present paper aims to validate a tool which enables identification of eco-efficiency potentials without complex calculations, the actually conducted refurbishment is modelled for several predefined refurbishments as well as the actually performed measures. As the tool aims at the identification of potentials, its results are not directly comparable to other quantified simulation or measurement results in terms of eco-efficiency. For energy savings, however, the simulation framework is fully compliant to state of the art methods and can therefore be assessed on a quantitative level. The scenarios for the modelling of energy saving potentials have been derived from [3] and are adapted based on the building stock available at Rintheimer Feld. The two basic scenarios are “conventional” and “innovative”, where “conventional” does cover the minimum legal requirements given by the Energieeinsparverordnung EnEV [29] and “innovative” includes the implementation of state of the art materials and insulation thicknesses of increased energy efficiency, resulting in an energy efficiency of a low-energy building.

The results of energy efficiency aspects are shown in Table 1, including both modelling results and actual savings as measured in the field. While the calculation of the heating demand before refurbishment shows high concordance, the resulting heating demand of the refurbished buildings is varying between the results of the conventional and the innovative scenario. Based on energy efficiency of the actually conducted measures, one of the scenarios was chosen. When the construction periods are taken into account, the energy demand on district level shows a deviation of 1,6 %.

Table 1: Heating demand modelled in comparison to measured or planned savings based on [26]

Building Type	Heating demand (Tool)	Heating demand (actual)		Deviation of refurbishment scenarios from actual savings			
	Before	Before	After	Before	Conventional	Innovative	Chosen
1	146.3	147.6	39.1	1%	80%	6%	Inno
2	121.0	120.8	60.9	0%	-6%	-43%	Conv
3	111.2	98.0	40.0	12%	56%	-5%	Inno
4	149.6	151.5	64.5	1%	9%	-36%	Conv
5	149.9	138.0	63.2	-8%	11%	-34%	Conv
6	127.1	187.0	50.0	47%	14%	-31%	Conv
7	149.9	124.0	51.0	-17%	38%	-19%	Inno

The economical saving potential was modelled based on the conditions given by [26], considering a timeframe of 30 years and an average energy cost development based on [30, 31]. For the ecological saving potentials, the standard conditions of the tool have been applied. On district level, the implementation of a district heating network was modelled based on typological information of the district publically available. In addition to the district heating, the implementation of a chp plant was modelled to show the potential impacts on the integration within the district. However, as the City of Karlsruhe already offers a district heating network powered by a coal-fired power plant and waste heat from a refinery, the scenario including the local installation of a chp plant cannot be compared using measurement data.

Table 2: Effects of different chp plant specifications on the predicted district eco efficiency (including refurbishment measures)

Chp plant specification	chp properties			Resulting Eco-Efficiency	
	Nominal power (kW)	Chp heating fraction	Full load hours (hr)	Ecological savings	Economic savings
No chp	0	0%	0	39%	8%
Standard chp	487	35%	8039	30%	12%

Maximum heat fraction	1660	63%	4535	49%	4%
Maximum economic savings	2015	61%	3641	50%	12%
Maximum ecological savings	1920	62%	3887	50%	11%

Table 2 shows the scenarios of chp plant specifications and resulting Eco-Efficiency changings. Next to a standard dimensioning covering 22,5 % of the maximum monthly heat demand as net thermal output [32], several scenarios based on optimization algorithms are shown. While the maximization of heat coverage does not induce any improvement on ecological or economic aspects, the other optimization scenarios offer significant efficiency potentials on both aspects. The standard chp dimensioning does not result in an ecological improvement, but slightly increases the predicted economic saving potential. Both economically and environmentally optimized chp dimensioning are resulting in a significant increase in ecological as well as economic saving potentials, indicating an optimum chp plant dimensioning of roughly 2000 kW nominal power.
The final results are depicted in form of an eco-portfolio shown in Fig. 3. For all refurbishment scenarios the integration of a chp plant is beneficial, although the integration is most useful for the conventional scenario. The viability of the refurbishment in terms of ecological and economic improvement of the district is given as shown in in Fig. 3. For the economic saving potentials, the results are comparable to the project results [26]. However, the saving potentials given through the implementation of a chp plant have not been realized and can therefore not be included in the validation. For the ecological saving potentials, the envisaged saving potentials of 80 % could not be confirmed, as for all scenarios a maximum saving of 50 % is predicted. This mainly occurs due to the fact that not only the use phase is taken into account, but all life cycle phases of the refurbishment components are included.

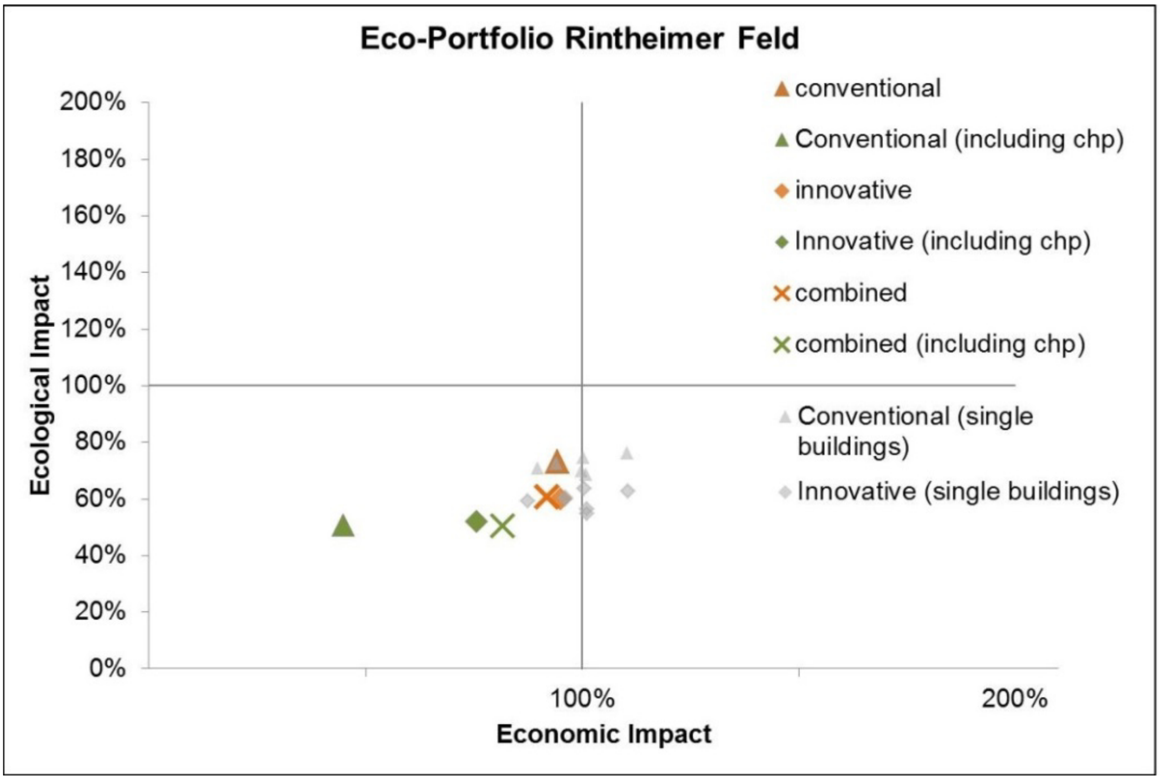

Fig. 3 Eco-Portfolio showing ecological and economic saving potentials of the district Rintheimer Feld on building level and on district level including the integration of a chp plant (optimized for ecological savings)

4. Discussion

The applicability of the developed methodology has to be assessed for several aspects. As described above, the tool aims at decision support in very early project stages, requiring a minimum amount of information for modelling. Therefore it is not required to quantify the eco-efficiency potentials of the refurbishment measures in detail. However, this does not apply to the energetic savings, as these deal as a basis for refurbishment decisions anyway. Within the case study and several other applications of the methodology, the predictive quality of the method has been proven. However, if the precision of predicted saving potentials has to facilitate a profound decision basis, the actually occurring energy savings have to be considered. As this does not occur for very detailed calculations as well, the restriction on simple algorithms with simultaneous consideration of inhabitant behavior can be considered to lead to appropriate results [28]. Furthermore it is advantageous not to claim to be able to assess the resulting energy savings precisely, as the user behavior superimposes the energy simulation results making these efforts unnecessary.

5. Concluding remarks

As decision-makers nowadays are increasingly aware of environmental aspects, a systematic approach based on low-threshold applications is necessary to include ecological aspects in the early planning stages of any refurbishment project. The present methodology successfully shows, that the saving potentials of district refurbishments in terms of economic and ecological efficiency can be predicted solely based on data already available in initial project stages. This facilitates the integration of ecological considerations from the beginning, allowing to identify districts of promising saving potentials at the beginning. However, it would be most beneficial if the model could be used to accompany the project planning, as decisions within planning phase then would base on a consistent model. Further optimization potentials are identified in terms of an enhanced implementation of user behavior. As the tool is used in practice and is continuously evaluated in terms of prediction precision, the integration of user behavior impacts can prospectively be considered more specifically based on actual energy savings compared to predicted potentials. Within the next steps, the tool will be expanded to also cover non-residential buildings such as educational institutions and commercial buildings.

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Potential and Risk for Zero-Energy-Buildings under Defined Urban Densities

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Summary

The aim of this paper is to develop a method to evaluate the potential and risk of renewable energy development by examining the land-use requirement of zero energy building (ZEB). To date there is still a lack of knowledge about which kind of building and which kind of building arrangement would be optimal to save as much as possible land for compensating measures of ZEB. How does the compensating area change with number of floors or plot ratio? Does the compensating area required by one unit of area of use increase or decrease with the number of floors and plot ratio? We intend to develop a method to address these questions and draw the attention to further explore the relationship among the variables. Some of the suggestions about the planning of land-use requirement of energy production could be derived from our preliminary results: 1) to save land for compensating measure, small number of floors should be used; 2) to save land in general, high plot ratio should be used. And, within the high plot ratio, small number of floors should be used. With the results of this research, we hope to contribute to the discussion about urban sprawl and compact city. We also hope to further advance the investigation about the relationship between urban density and energy production. It may also encourage land-use policy makers to include land-use requirement of renewable energy production into consideration.

Keywords: Zero Energy Building, compensating measure, urban densities, energy demand, land-use requirement

1. Introduction

In order to bring primary energy consumption and CO2 emission to zero, one of the contributions is to optimize buildings to become zero energy buildings (ZEB). Primary energy consumption includes thermal energy for heating, cooling, and hot water as well as power for mechanical ventilation and artificial light. This energy demand can be minimized by architectural techniques but it is not possible to bring it to zero (e.g. time of use during dark hour's leads to the use of artificial light). To reach zero, the remaining energy demand has to be covered by building services using renewable energies.

The purist definition of a ZEB claims that this energy is to be gained on-site (from the building envelope or the ground under or near the building) or off-site [8]. This leads to the competition between the area of use to be served, which creates energy demand, and the size of building envelope or the size of the estate to cover this demand with renewable energies. A wider definition would allow producing a part of the energy off-site (outside of town) on compensating areas, which could be covered with wind turbines, PV modules, sustainable agriculture, etc. We will call that a zero energy building with compensating measures (ZEB_CM). From an ecological point of view both versions of a ZEB have the same zero contribution to CO2 emission and they are adequate options.

In a city with very high urban density, the purist ZEBs are often not possible. Or, vice versa, the trial to derive a city with purist ZEB's would lead to a limited urban density which would be below urban densities known as optimal for public transport systems (and minimized transportation energy) and a liveable urban situation. A ZEB_CM opens a way for an ecological development respecting these other criteria.

But even if we assume such an "optimal" urban density as a precondition we do still not know which kind of building and which kind of building arrangement would be optimal to save as much as possible land for compensating measures. The comparison of land-use requirement of ZEB and ZEB_CM respectively will deal with some interesting questions: How does the compensating area change with number of floors or plot ratio, which is the ratio of 'area of use' and 'estate area'? Does the compensating area required by one unit of area of use increase or decrease with the number of floors and plot ratio?

The aim of this paper is to develop a preliminary method to evaluate the potential and risk of renewable energy development by examining the land-use requirement of ZEB and ZEB_CM. We intend to develop a method to address these questions and draw the attention to further explore the relationship among the variables. It may also encourage land-use policy makers to include land-use requirement of renewable energy production into consideration.

2. Methodology

The method used for this paper was developed for a master course "Climate Responsive Architecture and Planning". Here the potential of ZEB and ZEB_CM was explored for fifteen big cities in all main climate zones around the world. The target of the course is to derive design rules for ZEB and ZEB_CM, to carry out design of building types and type facades, to develop rules for building distance and urban density, and to investigate the required space for compensating area.

For this paper we choose Singapore as the case study for the following reasons. Firstly, the Singapore Master Plan (MP) [10] provides very detailed land-use plan, which includes very specific regulation about building height and plot ratio. It shows the permissible land-use and density for developments in this highly densified city. The plan offers us a good starting point to explore the relationship between building height, urban density, and compensating area by examining the existing plan. Secondly, Singapore government has been very encouraging in the development of ZEB [2]. However, there is also a huge demand for additional area of use and high-rise building [10]. If the ZEB_CM requires additional land, it would be a critical issue for Singapore government to balance the need of land for energy production and other land-use needs. Finally, the consideration of land-use needs has been clearly stated in the MP: "Given the constraints of the small land area, the Master Plan and the Concept Plan have played a vital role in helping to balance many land-use needs in the following six key focus: Housing, Transport, Economy, Recreation, Identity, and Public Spaces"[10]. To date, we have not found any indication that energy production is included as one of the needs for land-use in the MP. In this paper, we intend to offer some information as reference for the future planning of Singapore to integrate ZEB into the land-use requirement.

Before we start the investigating there are several preconditions with regard to the definition of building types, comfort models for summer, and regenerative building services. The analysis focuses on office buildings.

2.1 Definition of standard office room, building type and building mode

A standard office room for 12 users (area of usage 168 m²) was predetermined to gain comparable result. It was assumed that this room could be one of a series of rooms, situated in the middle of an office building so that the building can be thought as continued horizontally and vertically.

The target of the university course was the optimization of this room to local climate and conditions by architectural technologies to bring energy demand to its minimum. For the different climates different types of building mode are possible: Adaptive, air-conditioned or, as a combination of both, hybrid.

An adaptive building is understood as a building with natural ventilation where the users can adapt their surrounding according to their preferences: Operable windows, personal switches for artificial light, thermostats, etc. Besides heating with standard systems, cooling is also possible with thermally activated ceilings. In adaptive buildings, the expected comfort temperature is assumed as in accordance with adaptive comfort models [1, 3], where above 20°C indoor comfort temperature varies slightly with the mean value of outdoor temperature. This assumption avoids waste of energy or saves energy for cooling.

In air-conditioned buildings temperature is controlled by building services (mostly to 26°C). The use of mechanical ventilation systems is standard.

Singapore has a hot and humid climate where outdoor temperatures are predominantly above comfort limits during daytime. For this reason we assume in this paper that the building is run in air-conditioned mode. Nevertheless there are also chances to run the building partly in adaptive mode, saving power demand for mechanical ventilation and cooling and thus leading to still better results.

To retain chances of a partly adaptive use the optimized standard office room for Singapore has a building depth of only 8.75 m to allow natural ventilation. The geometry of the optimized room is presented in figure 1.

The energy demand of this optimized room is determined with energy plus based transient simulation software (Primero-Comfort [9]). The effect of buildings shadowing each other and influence on power demand for artificial light is included.

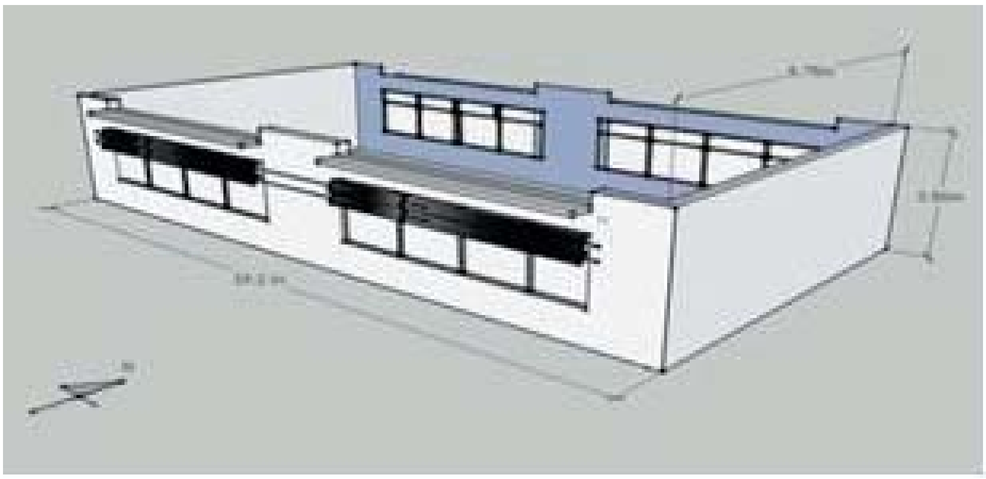

Fig. 1 The design of the optimized room with the design of overhang (width: 19.2m, depth: 8.75m, height: 3.5m).

2.2 Building services and renewable energy production on-site (ZEB)

The renewable energy concept is based on a combination of two systems for thermal and electrical energy. A geothermal system uses thermal energy from the ground (heat exchangers up to 100 m depth are assumed) which is transferred to the right temperature for heating and cooling with a power driven heat pump. The power production is delivered from PV modules mounted on the building's roof.

A purist ZEB produces all energy on site. Thus, the peak in heating or cooling power determines the necessary size of the geothermal system. Because the ground between two buildings can be used only once for geothermal systems this determines finally the minimal size of the estate and thus the building distance. For power it is assumed that the grid can serve as storage. The necessary size of PV modules is thus determined by the yearly power demand of the building. Because we assume only the roof as possible area for PV this determines finally the maximal number of floors producing this power demand. Thus, number of floors and building distances are not free of choice but determined by the target to reach a ZEB.

In Singapore there is no heating demand; table 1 shows the strategy for cooling and the assumed coefficients of performance (COP).

Table 1: Cooling strategies, resulting COP for power demand

Priority	Cooling system	Power demand
1st	Geothermal and thermally activated ceiling, natural ventilation	Heat pump COP 2.5
2nd	Geothermal and mechanical ventilation. Standard air change 2 1/h	Heat pump COP 2.5 plus power demand for ventilation
3rd	Standard chiller, mechanical ventilation. Standard air change 2 1/h	Chiller COP 1.5 plus power demand for ventilation

2.3 Building services and renewable energy production on-site and off-site (ZEB_CM)

For a ZEB with compensating measures (ZEB_CM) the number of floors and building distances are free of choice and defined by other principles like minimal urban density, liveability, etc. From the predefined building distance the maximal power of the geothermal system can be calculated backwards as well as the maximal yearly power generation from the building's roof. Both are compared with the real energy demand for thermal and electrical energy. If a part of these energies is not covered it has to be covered by compensating measures off-site to reach a ZEB_CM.

In Singapore we have only cooling and no heating. That leads finally to only power demand to serve all systems. Thus, compensating measures means power production off-site. To be fair the same PV modules like on the building's roof were assumed to determine the necessary compensating area.

Of course, renewable power production off-site could be replaced by other systems like wind turbines on- or off-shore, power plants, etc. Based on data for the energy density of these systems [5], it can be estimated that PV modules gives the best values. Thus, for all other systems the compensating area will be larger than the one we used in this paper. On the one hand, we assume that PV modules cover the whole land and no other use is possible. On the other hand, wind turbines have a smaller energy density for power production but cover land only point by point, leaving space for other uses like agriculture. Thus, regarding energy density, it is not the end of the story, further investigation would be necessary here to clear up the interdependencies.

2.4 Singapore government's urban plan

Singapore government's urban plan (see figure 2) controls the plot ratios for further city development. Supplementary the building heights are limited by a given maximal number of floors depending on the plot ratio (5 floors up to pr 1.4, 12 for 1.6, 24 for 2.1, and 36 for 2.8) [10].

Fig. 2 Example of Plot Ratio Plan developed by Singapore's Urban Redevelopment Authority showing city center [10]. The indicated numbers are the given plot ratios.

Table 2: Different investigated variants according to Singapore government's urban plan

Variant	Description
Purist ZEB without compensating measures	
1	• 3.4 floors as a result of PV power production on building's roof • Building distance according to peak cooling demand and geothermal system. But the resulting distance is less then prescribed by Singapore standard. Thus Singapore standard is assumed with building distance 12 m and plot ratio 1.4
ZEB_CM with PV modules off-site, pr 1.4, 2, 2.5, 3, 3.5, and 4.2	
2	• 8 floors • Building distance according to respective pr
3	• 12 floors • Building distance according to respective pr
4	• 24 floors • Building distance according to respective pr
5	• 36 floors • Building distance according to respective pr

Exemplarily we chose plot ratios of 1.4, 2, 2.5, 3, 3.5, and 4.2 for our investigation. Because we want to investigate if the given combinations of pr and floor number are optimal, we do not follow Singapore's rules and assume for all pr a variety of 8, 12, 24, and 36 floors. From this, building distances can be calculated accordingly based on the pr. The results lead to the 5 investigated variants described in table 2.

3 Results

In this paper we aim to explore the relationship between urban density and required compensating area in order to meet the target of land-use efficiency. We propose that urban density could be evaluated in several ways. Firstly, it can be evaluated by how much total space is required and how the total space requirement varies with number of floors and plot ratio. Secondly, urban density can also be evaluated by land-use efficiency, which is measured by the size of the compensation area that is required for each unit of area of use. Finally, we would like to address the issue about energy sprawl, defined as the product of the total quantity of energy produced annually (e.g., TW hr/yr) and the land-use intensity of production (e.g. $km^2$of habitat per TW hr/yr) [12]. In order to examine the energy sprawl created by the requirement of compensating area, we compare the changes before and after compensating area are included into the calculation of urban density.

3.1 Measuring the level of space-saving

The measurement of space-saving consists of two indicators. Firstly, the level of space-saving can be measured by compensating area. Compensating areas of buildings with different heights and plot ratio are then compared. Secondly, the sum of estate area and compensating area is compared among buildings with different heights and plot ratio.

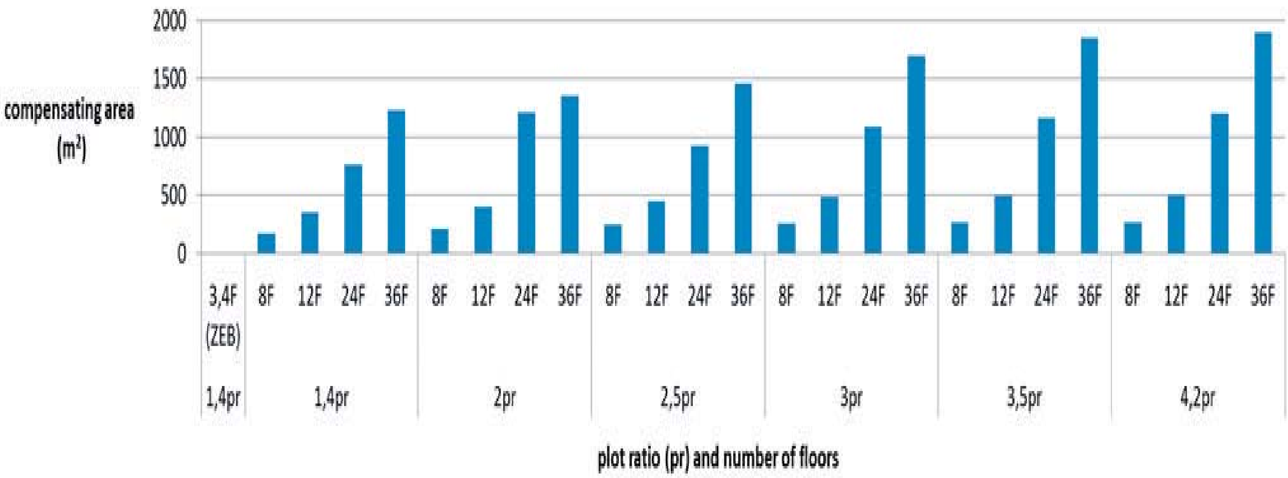

Fig. 3 Required compensating area by building height and plot ratio.

The results presented in figure 3 show that, comparing with a low-rise building, a high-rise building requires more compensating area. And the compensating area increases with plot ratio.

But we propose another indicator which highlights the interdependencies in a clearer way: Space-saving should also be measured by the total required area, including both estate area and compensating area. The results in figure 4 show that, the higher the building, the larger total area is required. However, the total required area decreases as the plot ratio increases.

Fig. 4 Total required area by number of floors and plot ratio.

3.2 Evaluating the land-use efficiency of energy production

Land-use efficiency of energy production is measured by the ratio of compensating area and area of use, which represents the need of compensating area for each unit of area of use. This standardized compensating area makes it easier to carry out comparison of land-use efficiency among different types of buildings.

$$\textit{Land-use efficiency} = (\textit{compensating area}) \,/\, \textit{area of use} \qquad (1)$$

The results in figure 5 show that, for each unit of area of use, a higher building needs more compensation area than a low-rise building. The results also show that, the larger the plot ratio, the more compensating area is required for each unit of area of use. This means low-rise buildings and small plot ratio are in fact more efficient in land-use in terms of energy production.

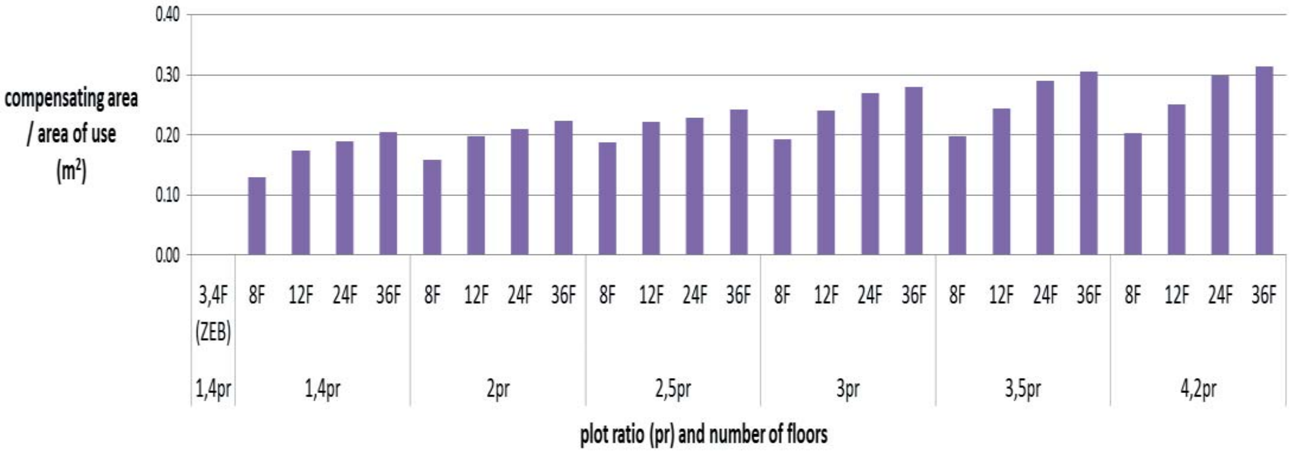

Fig. 5 Ratio of compensating area and the area of use by number of floors and plot ratio.

Furthermore, it would also be interesting to examine the ratio of the total area, i.e. the sum of estate area and compensating area, and area of use.

$$\textit{Land-use efficiency (2)} = (\textit{estate area} + \textit{compensating area}) \,/\, \textit{area of use} \qquad (2)$$

The results in figure 6 show that, the total required area per unit of area of use increases with number of floors and decreases with plot ratio. This means that, when estate area is included, low-rise buildings and larger plot ratio are in fact more efficient in land-use in terms of energy production.

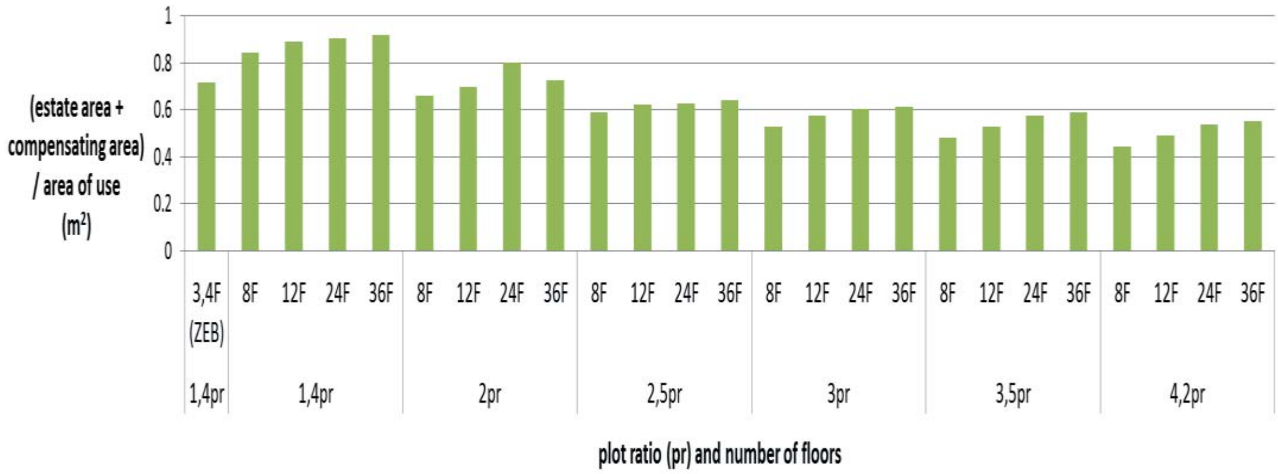

Fig. 6 Ratio of total area and the area of use by number of floors and plot ratio

3.3 Effect of compensating area on urban density

A measure for urban density is the plot ratio, which is:

$$(urban\ density=)\ plot\ ratio = (area\ of\ use) / (estate\ area) \quad (3)$$

Due to the requirement of compensating area to supply renewable energy, we are also interested to examine the changes in the urban density when compensating area is included in the calculation. We define the extended urban density as:

$$extended\ urban\ density = area\ of\ use / [(estate\ area)\ ) + (compensating\ area)] \quad (4)$$

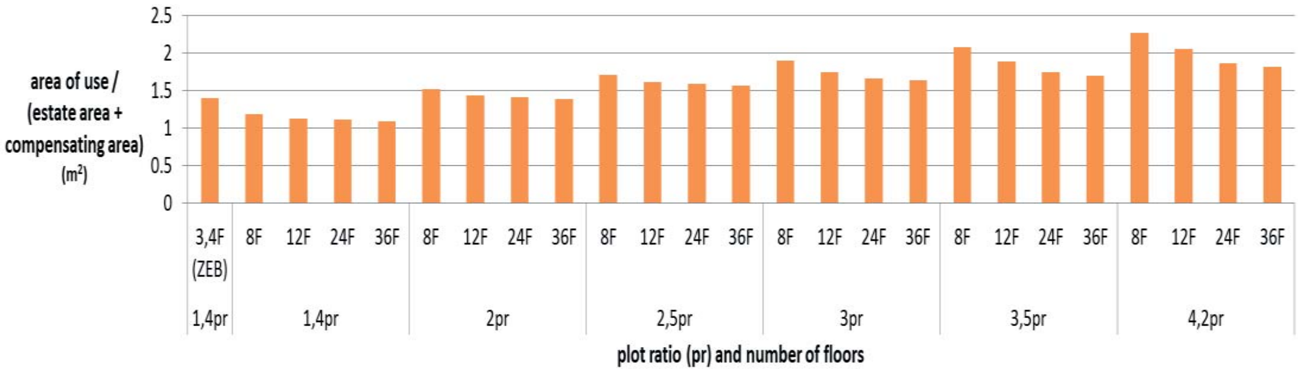

Fig. 7 Extended urban density by number of floors and plot ratio

Comparing the urban density (plot ratio) and the extended urban density with different building heights, the results in figure 7 show that extended urban density decreases with number of floors but increases with plot ratio. This means that, the taller the building, the larger the difference between original density and the extended density. And the differences is even greater in large plot ratio than the small one.

4 Discussion

Based on the results in previous section, we derive some general suggestions with regard to the planning of land-use requirement of energy production:

- If the priority of land-use planning is to save land inside the town, use high plot ratio.
- If the priority of land-use planning is to save land for CM, use a small number of storeys.
- If the priority of land-use planning is to save land in general, use high plot ratio. And, within high plot ratio, use small number of floors.

Supplementary we give some comments to the physical aspects which lead to the results. The detailed noted figures for pr, COP, etc. are special for the location and will be different for others. But the discussion shows also the general tendencies:

- Up to pr 2.5 the building distance is big enough to cover the whole cooling demand with basic cooling (geothermal, heat pump, thermally activated ceiling)
- For higher pr, the estate is fully used for geothermal but a part of cooling demand is still not covered, we need standard chiller with worse COP and thus higher power demand.
- Up to pr 2.5 there is remarkable influence of shadowing and the resulting power demand for artificial light. The lowest power demand (best daylight access) here is with the higher number of floors and bigger distances. For plot ratio 3.5 and higher, the shadowing is so strong that artificial light has to be used the whole time, independent of number of floors.

Our results in section 3.4 show that the inclusion of compensating area changes the urban density. This variation increases with number of floors and plot ratio. If Singapore government takes compensating area into the consideration of the future plan without changing the plot ratio in the current plan (5 floors up to pr 1.4, 12 for 1.6, 24 for 2.1, and 36 for 2.8), the number of floors will need to be reduced. As the results in figure 7 shows, the differences between urban density and extended urban density is smaller when the number of floor is smaller.

Our results lead us to the questions in the next step: is it possible to include compensating area in the land-use planning in Singapore? At first glance, high-rise and high-density developments seem to be simple ways to circumvent the limited land. However, high-rise building increases the demand for larger compensating area. On the other hand, there are a little bit more than 50 percent of the areas that are reserved for airports, ports, sewage treatment plants, and water catchments [11]. For the future planning, we propose that areas with the potential for multi-usage, such as compensating area for renewable energy production, should be identified and calculated. Then the regulation of building height can be derived by using the methods proposed in this paper. Meanwhile, we suggest that methods for the estimation of compensating area, the variables that contribute to variation in energy consumption, and the comparison among districts should also be further refined and developed in the future research.

5 Conclusion

We hope that this paper can contribute to the discussion about urban sprawl and compact city by including building energy consumption and renewable energy production on-site and off-site into the considerations. Also, the discussion about urban density and energy production is often focusing on population density. It is our attempt to propose a supplementary measure by exploring the relationship between building density and energy production. Finally, this paper intends to fill the gap between building design and energy density, which is about the relationship between different types of energy production technologies and land-use requirement. We propose that the land-use planning of renewable energies does not only need to measure energy density, but it should also consider how much land is required with different building design. The possible further development of this paper would be to include more cases in different climate zones and to carry out comparative studies. Alternatively, it may also be interesting to look further into other aspects of land-use policy in the selected city and discuss about the balance among various land-use needs with a more holistic view by including land-use requirement of energy production into consideration.

6 Acknowledgements

The authors would like to thank Yu-Chi Lien and Octavio Molina, who were the master students working on the case of Singapore in the course of Climate Responsive Architecture and Planning and also contributed the drawing of the room design.

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Pre-Design Steps for Regeneration of Urban Texture

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Summary

The following paper provides an overview of author's last academic project focused on regeneration of urban texture. She worked on this project - entitled "Theory Fundamentals & Practical Patterns of Interventions in Urban Texture, in Contemporary Iran (Case Study: Navab Project \ Tehran , on the Basis of Regeneration Approach)" - as her thesis for Master of Urban Design at University of Tehran. The paper is in line with the topic of sustainable neighbourhood and urban development by describing a method for redesigning the access network (including both riding and pedestrian), developing public open space, and injecting new functions in a decaying urban quarter. The context of case study is historic centre of Tehran, the capital of Iran, which was the original core of city formation in the past and is presently situated at the heart of the contemporary city.

Keywords: urban regeneration, neighborhood, pre-design method

1. Introduction

One of contradictions between heritage conservation and urban sustainable development could be identified when dealing with an old quarter of city, suffering from the problem of insufficient traffic accessibility and permeability. This problem usually turns out to be a major one, since it itself raises other social and environmental difficulties not only for close by areas but also for a much larger part of city or even sometimes the entire city. As long as there remains the problematic situation, such an aged neighborhood is most likely - or at least the case study of this project was - inhabited by lower income and socially vulnerable groups living in unsanitary conditions and high risk housing. As a result, it does not appeal to investment activities and forward looking urban intervention practices due in part to uncertainty about the success and profitability. However, according to the criteria of heritage conservation, urban fabric of the neighborhood is generally considered worthwhile for preservation. It is the built inheritance from the city's past which needs to be protected as an entity. Thus, on the one hand, the historic access system requires to be redefined mainly by retaining those narrow pathways within the densely compact texture and deploying them as the basis of any change. On the other hand, it is highly essential that the structural order of public space in the neighborhood area get revitalized. Either way, there are other needs to be met; for instance, the demand for more public parking lots for residents and above that to have open and green space expanded as well as public services with regard to land use.

2. Motive and Background

Before describing the pre-design method which was innovated and employed with regard to this academic project, the case study area is briefly portrayed in the following paragraph. It basically helps to clarify the logic and soundness of the whole proposed process, and how come the author believes that this method could be applicable to other urban settings as well.

The case study is an urban area of 125000 m^2 with a population of 5000. The quarter is called 'BolurSazy Quarter 7' which is located in district 3 of region 17, central Tehran[1]. This small and sparsely populated neighborhood - and yet with high spatial density and compact texture - has been largely affected by Navab[2] Project Phase IV. Thus, part of its texture along the east side has been recently purchased and demolished. Besides this 30-metre depth of desolated land, approximately the whole context suffers from decaying. The texture of the quarter primarily includes two-floor residential buildings. Most of them have possession documentation and occupancy background for at least 30 years. There are sparsely single, three or four-storey residential buildings. A deficiency of public services in the land use can be considered, since there are only a few retail shops in the area. Also, a significant number of plots at the north edge of the quarter are assigned to incompatible functions. Another point can be noticed concerning religious spaces which are adequately active and socially spiritual.

Area: 12.5 Hectare

Habitant Population: 5,ooo Unit

Available Streets: 2 (Helal-e-Ahmar, SheykhMohamady)

Available Alleys: 6

Available Dead End Alleys: 66

Residential Plots: 668

Residential-Commercial Plots: 37

Commercial-Industrial and Religious Plots: 72

Fig. 1 existent state of the urban texture

[1] To give a sense of scale, the information below on Tehran:
Area: Urban 730 km^2 (280 sq mi) Metro 1,274 km^2 (492 sq mi)
Population (2012): City 8,244,535 Density 10,327.6/km^2 (26,748.3/sq mi) Metro 13,828,365

[2] Navab street was an old north south street playing a vital role in central Tehran within the last 70 years before implementing the large scale project (reconstruction of old houses to medium and high rise buildings and construction of a new highway) which later proved to be a big failure.

In addition to the outcome of fieldwork, the project benefited from a survey on local willingness for participation[3]. It is a key feature of methodology upon which the pre-design idea was founded and developed. The types of participation, as categorized in the questionnaire are shown in the figure below:

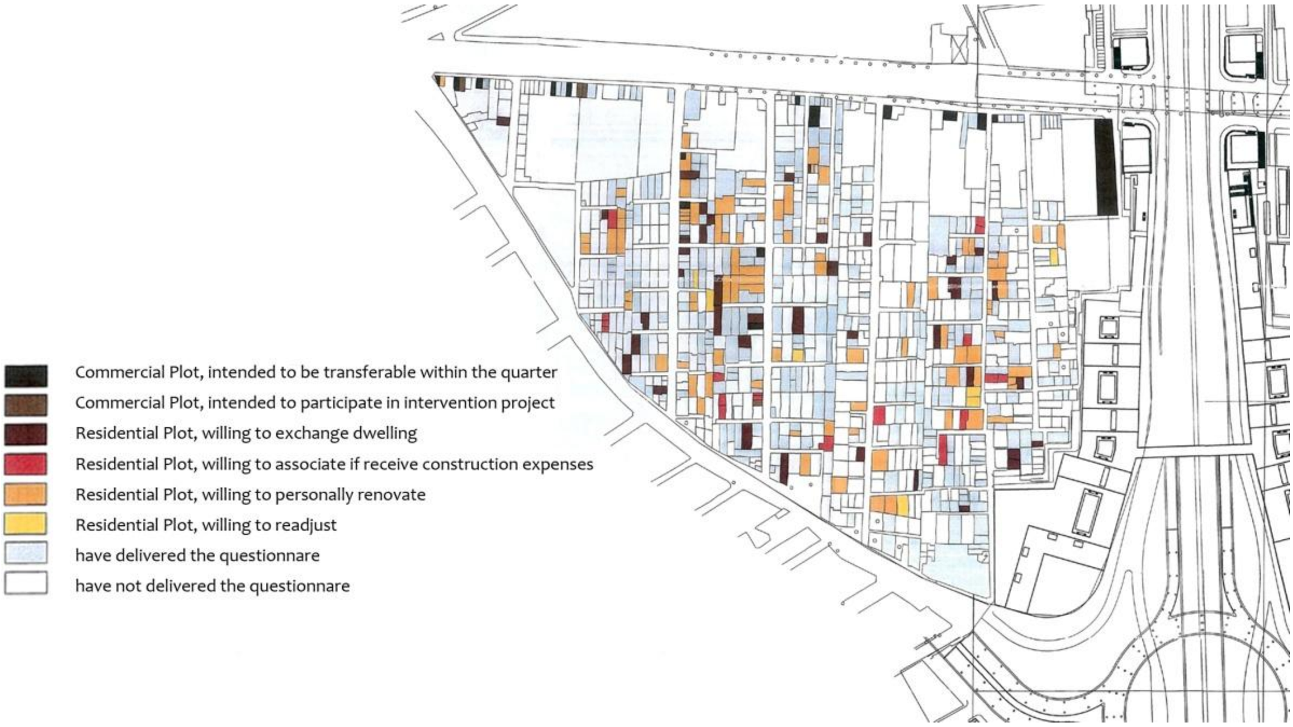

Fig. 2 types of participation

The three reciprocating steps of pre-design method will be explained in the following paragraphs. Still beforehand, it should be mentioned that - based on recognition and analysis steps - an extensive literature review of pertinent references was done to extract and set up the precise theoretical foundations for the project. As a result, the project's outlook, goals, objectives, and eventually some theoretical strategies and practicable solutions were outlined in planning step. Then, based on recognition and analysis steps, three different preliminary conceptual alternatives were proposed on how to fulfill the project's objectives.

Fig. 3 one of the conceptual plans drawn in planning step of the project

[3] This survey was conducted by Tehran Province's Housing Foundation of Islamic Revolution, in 2003.

In short, planning professionals should treat heritage conservation and sustainable development as not opposite and not even equal but as supplementary aid one for the other. Keeping this in mind, starting point for pre-design method hinged on the aim of minimizing probable unavoidable demolition of building plots (including: residential, commercial, and etc.). In order to protect the valued urban texture and aged houses located within, most of which privately owned or rented, a process-led intervention was planned.

3. Pre-design Steps of the Project

As mentioned above, there were three conceptual plans made in planning step of the project. To reach a final alternative, comparative evaluation led to a composed final alternative which was an optimum choice of those three. The set of criteria for the evaluation included:

- securing riding and pedestrian accessibility with most permeability,
- expanding public realm,
- maximum exploitation of participational forces,
- minimum demolition,
- safety and security,
- defining the spatial hierarchical order,
- eliminating present problems,
- avoiding extreme idealism,
- motivation for future.

It is worth stressing that the final conceptual plan was made to enhance the effectiveness of pre-design's result. In other words, it was considered to be a guiding schematic plan which (next in pre-design steps) helps with both taking advantage of local willingness for participation and keeping a balance between development and conservation of urban texture in a sensible manner. It was more like the last general ideas of how to make regeneration happen in the site, just before the current realities (i.e., threats and opportunities known by outcome of the survey) were taken into account.

It is very important for planners to be aware of and committed to their role in finding some innovative ways to revitalize a historic urban texture, no matter what limitations there exist or how challenging it is regarding various political and economical circumstances. Following the current realities of participation - in each specific case - sometimes shines a whole other light on things than does the international literature on participatory planning. This issue of participatory approach has been globally open to debate since many years. We will most likely never come up with some universal ideas on it, because not every context brings us the same real-time story to be a part of. The author finds such attitude very worthwhile and has been trying to obey it, so that this project shall not just be another publication. Thus, underneath it all, it was intended to contribute to this broadening agenda by signaling that the cautious use of on site potentials is applicable to any urban settings in the world. Only, it requires planners to go through a non linear process. Regeneration planning in a historic city is not a one way road of planning and designing, but rather you have to review and rethink your concepts over and over again well in advance. That is basically why this project came up with pre-design method. Furthermore, it has to be underlined that the pre-design steps (described in below) are derived from a back and forth process of at least three times revision. However, herewith, the upshot of this process is being reported; only those three steps which finally provided the most optimal conditions altogether.

3.1 Pre-design Step 1:

As in the first pre-design step, specific plots among those which landowner declared not contributing towards participational intervention in any way but selling were chosen* to be purchased and demolished (49 Residential Plots & 3 Commercial Plots).

* [Note: According to heritage conservation principles, there were some parallel criteria which filtered out (physically or functionally) precious buildings to be preserved, despite the feedback from landowners.]

Fig. 4 pre-design step 1

3.2 Pre-design Step 2:

Second, specific plots among those which landowner willingly exchanges dwelling were chosen* to be purchased and demolished (17 Residential Plots). Also, specific plots among those which landowner agrees to be transferred within the quarter were chosen* to be purchased and demolished (4 Commercial Plots). By then, with the benefit of potentials of the context, some free-to-be land was identified in order to enable finalizing the optimal design alternative. Besides, it was noted that executive organization is in charge of providing temporary places for participants. Prefabricated units were suggested.

Fig. 5 pre-design step 2

3.3 Pre-design Step 3:

Through the third step of pre-designing, redefined access network was proposed in more specific details. There were three levels of priority for riding, riding-pedestrian, and (exclusively) pedestrian accessibility:
1. main roadway loops with separated sidewalks on either side
2. subordinate routes with mixed traffic
3. footpaths only open to emergency and service riding traffic.

Fig. 6 pre-design step 3

Then, from this point on, the project continued on smaller scale of urban design. After situating the public open realm (including: roadways, sidewalks, parking lots, mixed traffic routes, footpaths, open and green spaces) in lands which have been purchased before, readjusting the functions and activities could be done. In this case, requirements of functions were:

- educational: nursery, kindergarten, primary school
- commercial: for daily and weekly shopping
- recreational athletical cultural: park, playground, pitch, library, multi functional community centre, exhibitional pavilion, newspaper stand
- medical: clinic, pharmacy.

Finally, revitalization of the main structure was on the basis of spatial and functional relations. Public activities were centralized in the central open spaces. Subordinate routes with mixed traffic connected public spaces of the quarter and neighborhood units. They provided accessibility to more plots. Additionally, they coordinated with characteristics of context.

Fig. 7 proposed intervention plan and structure of a designed public open space

4. Conclusion and Suggestions for Further Work

The method which was explained above could be sensibly applicable to broader contexts either in countries with similar urban planning background or even in European countries, since the whole process is independent of any specific governmental or technical prerequisites which constrict its applicability. As stated earlier, pre-design method emphasizes on the careful and thoughtful use of on site potentials by the planner through a back and forth process. Keeping a sustainable balance in the process of protection and use of built heritage cannot be handled by conventional mono-sectoral methods. Rather, it demands interdisciplinary constructs by combining insights from heritage conservation and sustainable development. Pre-design method encourages this viewpoint.

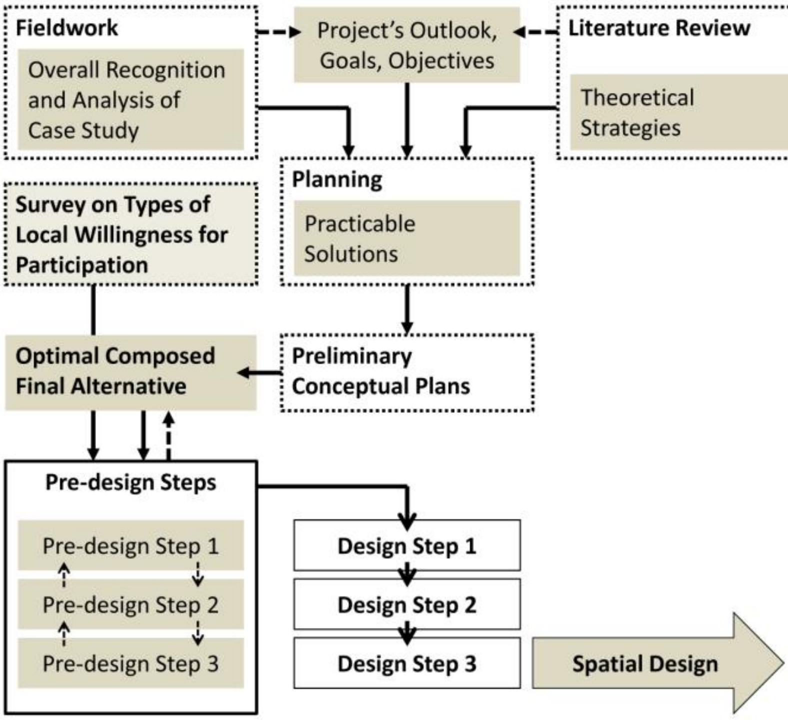

Fig. 8 process flow chart of the proposed pre-design method

Speaking of contradictions between heritage conservation and sustainable development in contemporary urban intervention practices around the world, I believe that - for the first thing - we (i.e., planners) need to question our current perceptions of heritage and sustainability. Despite all the ongoing and widely acknowledged theoretical debates on socio spatial dimensions of heritage and socio cultural aspects of sustainability, it seems that we have not yet shifted our attention to those non material spheres of the issue in an adequate empirical way. Actually, the situation we have to deal with is initially confusing itself; and this poses a big challenge to the management of many historical cultural urban areas, particularly in so-called developing countries. On the one hand, our origins (i.e., heritage) cannot be limited to physical bodies of some old buildings scattered around the inner city (Zukin, 2010), for even those appropriate (or worthy) selections cannot be kept or frozen forever after all. On the other hand, concerning the latest sustainability principles, we are now required to go beyond environmentally green and economically efficient planning strategies. Then if we agree on these more profound viewpoints, we (should) wonder what constitutes heritage which we protect and whether a better understanding of it would retain the dichotomies the same or not. Being involved in urban regeneration projects on neighbourhood scale during my graduate studies and afterward in Iran, I have been investigating Tehran's case as the archetype of problem at hand for years. As a result, by now, I am convinced that the Euro-American model of heritage (focused on material aspects) is not flawlessly applicable to contexts (like Iran) with radically different worldview. And to consider the issue on a broader canvas, this is to say that the dominant Euro-American model of heritage has lately been criticized, challenged, and subject to transform (Smith, 2006; Harvey, 2008). So, I intend to contribute to this broadening agenda by signaling that a shift from concern for 'things' to concern for cultures, traditions, and place-making seems urgent.

5. Personal Note

I am currently working on my doctoral thesis, entitled "Cities, towards Missing Identities? Synergy Management of Sustainable Protection and Use of Cultural Urban Heritage in the Context of

Global Change - the case of Tehran" which concerns the issue of urban identity focusing on non material components of built heritage. The research seeks an interpretive analysis of city's cultural background and its current state in order to represent a forward looking management framework for revitalization.

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Promoting Sustainable transport
Reviewing the case of pioneer cities

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Summary

An attention is required in addressing the interactions between transport and global warming; motorized transport is one of the factors that are responsible for global carbon dioxide emissions to the environment. Thus it is essential to encourage other sustainable ways of travel. Cycling is considered an environmental-friendly mode; it is an easy, cheap and clean transport mode that should be encouraged. There should be a clear plan for cycling in every city street; the cities need to be people-friendly rather than car-friendly, thus more liveable and more sustainable. The Netherlands, Denmark and Germany have made bicycling safe, convenient and practical way to get around in their cities. The research brings into focus the importance of promoting alternative clean transport modes to solve the cities pollution related problems, especially the city of Cairo. It reviews the case of the pioneer cities in Europe, illustrates their successful strategies and the possibility of implementation in crowded polluted cities.

Keywords: Bikeways, Streets, Cycling, Environment

1. Introduction

Cities are vulnerable to climate change this requires out attention in addressing the interactions between transport and global warming. The climate impact of transport systems is evaluated through the pollutant emissions and (GHG) emissions from motorized vehicles. The combustion of fuels leads to significant emissions which accelerate the environmental pollution and climate change in the long term. However, the value of the use of bicycles, has been ignored in many cities. Cycling is a low-cost and practical means of transportation that is non-polluting, energy efficient, healthy and fun. Cycling as a means of transportation has been growing in recent years throughout a number of countries as they work to create more sustainable transportation systems. Increased levels of cycling result in significant benefits to the environment and the people's life. The Netherlands, Denmark and Germany have been at the forefront to make cycling safe, convenient and attractive. A range of measures and programs used in them to promote cycling by a broad spectrum of society and at the same time improve cycling safety. The research concludes with an overall assessment of the principals that can be learned from these countries to make cycling safer, more convenient and attractive in other countries especially in Egypt.

2. Methodology

Though cycling is a tradition in a number of countries that has long been established, it is not yet introduced as a practical mode of transport in many other countries especially in Egypt. In fact, there is an absence of cycling as a mode of transport in the cities' streets. The probem statement of the research focus upon the absence of a systematic assessment on cycling concerning its contribution to the environment. There is a lack of availability of knowledge for the need of cycling and no data for its required facilities, hence, the absence of studies and projects regarding promoting cycling in the travel network of the cities and encourage people to cycle. Therefore, studying the cases of the pioneer countries and their measures in implementation of cycling within the cities' streets is needed. The research hypothesis states that cycling has a positive impact on the environment related problems such as solving the problem of the (GHG) emissions resulted from the motorized vehicles. In addition, promoting cycling in cities especially those suffering from congestion and pollution would solve traffic congestion and pollution related problems. Consequently, there is an essential need to put a plan of policies to be applied on the city streets, first to promote the existence of cycling as a mode of transport within the travel network through planned bikeways, facilities and traffic calming measures, and second, to encourage people for a safer, convenient and attractive mode. The main aim of the research is to promote cycling in cities' streets as a sustainable mode of transport through a set of policies to be applied especially in crowded polluted cities as Cairo. And in order to implement cycling within the travel network and to encourage people to cycle, this mode should fulfill three main issues which are safety, convenience and attractiveness. There are other minor objectives to this study; these are grouped under a number of main themes as follows:
Safety; to improve street safety by providing level of street safety and cycling training to people, by implementing infrastructure and design measures to improve street safety and to address and prevent anti-social behavior linked to transportation, health; Promote and encourage physically active and sustainable modes of travel such as cycling, environment; To promote the use of sustainable transport modes to help reduce congestion and improve air quality within the environment, and accessibility; to improve accessibility for cycling to different destinations, establishments and activities.

3. Sustainable transport

The transport sector is a significant contributor to greenhouse gases (GHG) emissions. The transport sector is responsible for about one quarter of global carbon dioxide emissions and emissions from this sector are growing more rapidly than any other. In conclusion, besides road safety, noise pollution, congestion caused by motorized vehicles, their (GHG) emissions, especially carbon dioxide, are long term concerns that threaten the sustainable development. Sustainable modes of transport are defined as walking and cycling. However, a sustainable mode of transport can be any mode that improves the physical well being of those who use such modes of transport, and are beneficial to the environment due to a reduced level of congestion and pollution. Unlike motorized vehicles, cycling does not create noise and emissions and it consumes much less non-renewable resources and requires less space for use and parking [1]. It is an environmentally friendly mode which should be promoted under any framework of sustainable transport. Cycling as a mode of transport helps to reduce the carbon footprint of urban transport. But it is threatened by the increasingly use of cars which support the accessibility and mobility of people, which in the long term would create dispersed land use not suitable for cycling.

4. Cycling in the Netherlands, Germany and Denmark

Cycling in many countries is a marginal mode of transport, used for recreational purposes but rarely used for practical, everyday travel needs. The social distribution of cycling is clear in young men doing most of the cycling, while women cycle far less, and the elderly hardly cycle at all. However, there are countries that have managed to make cycling a mainstream mode of transport, a perfectly normal way to get around cities. In the Netherlands, Germany and Denmark, cycling levels are more than in other countries. Dutch, German and Danish women cycle as often as men, and rates of cycling fall only slightly with age. Moreover, cycling is distributed evenly across all income groups. In these countries, cycling is for everyone and for all trip purposes. They have been the pioneer countries to promote cycling and make it safe, convenient and attractive. The success of cycling does not depend on poverty or the lack of motorized transport options to force people onto bikes. Cycling in these countries is not requiring expensive equipment, advanced training, or a high degree of physical fitness. Nor are cyclists forced to battle motorized vehicles on streets without separate bike lanes or paths. On the contrary, cyclists ride on simple, inexpensive bikes; almost never wear special cycling outfits or safety helmets.

5. Promoting cycling in cities

The cycling in previously mentioned countries had reached this level of success and convenience through the applications of certain design measures and government policies for promoting cycling in their cities; these can be grouped as follows:

5.1 The Government's policies

Local Governments in the Netherlands, Germany and Denmark have been planning for cycling for many decades, since the 1970s, however much earlier in some cities. These are a number of policies set by the government which could be followed in order to encourage cycling especially in crowded cities. They can share in promoting cycling indirectly; they provide more favorable conditions for cycling. First, car-use restrictions are applied, many Dutch, Danish and German created restrictions on car use, such as limited speeds, turns, direction of travel and in some cases prevent the use of car, such as in pedestrianized areas. In addition, the provision of street capacity and parking facilities is decreased [2]; [3]. This took place in many Dutch, Danish and German cities over the past few decades, the reduction of street and parking supply discourage car use in the city centre of big cities [4]. Consequently, the many restrictions on car use and parking had led to reduce the speed, convenience and flexibility of car travel compared to other mode such as cycling [5],[6]. Second; increased fees in license fees, driver training and parking fees, they are much higher in those countries than other places, in addition to the sales taxes on petrol and new car purchases [7],[8],[9]. This results in overall costs of car ownership and use higher than any other places. That high cost of car ownership discourages car use and promotes alternative ways of getting around, such as cycling, which is considered a cheap mode of transport. Third; Land-use and urban-design policies in the cities of those countries are generally much stricter than in any other country. The mixed-use zoning and the transit-oriented developments have a long history in these countries and in Europe in general. They facilitate the proximity of residential areas to commercial establishments, schools, churches and a range of services. The resulting trip distances are shorter and thus more bikeable than those in other places [6].

5.1 The Design measures

These are measures put by the three pioneer countries to promote the existence of cycling within their cities' transport network. They are categories of measures that have been adopted in many of their cities [6]. The success of accommodating cycling is due to the coordinated implementation of all of these measures, so they reinforce the impact of each other in promoting cycling.

5.1.1 Bikeway network

Separate bike paths and lanes expanded widely in these three countries between the 1970s and the 1990s [10], [11]. The bikeway networks in famous cycling cities in these countries_(Berlin and Muenster in Germany, Amsterdam and Groningen in the Netherlands, Copenhagen and Odense in Denmark)_ include numerous off-street short-cut connections for cyclists between streets and buildings to enable them to take the possible direct route from origin to destination. This had resulted in the making of a complete integrated system of cycling routes that permits cyclists to cover most trips either on separate paths and lanes or on lightly travelled, traffic-calmed streets. The design, quality and maintenance of cycling paths have continually improved. All related bikeway's facilities are improved as well, [12],[13] such as;

- The colored pavement treatments, which is used to highlight conflict areas between bicycle lanes and other lanes.
- The way finding system; this indicates direction of travel and all information for location and other destinations. Some cities have recently introduced Internet bike route planning to assist cyclists in choosing the route that best serves their needs. The internet program shows the optimal route on a map and provides all relevant information about time, average speed, bike parking and public transport connections.
- Bike signal heads; where they are mostly installed at intersections to improve identified safety for cyclists.
- Separate bikeways; represented in bike lanes and bicycle boulevard, the provision of separate cycling paths is the base of the Dutch, Danish and German policies to make cycling safe and attractive. This makes them designed to be safe, comfortable and convenient for both young and old, for women as well as men, and for all levels of cycling ability or seekers.

5.1.2 Bike Parking

The local governments and public transport systems provide a large number of bike parking facilities in Dutch, Danish and German cities. In addition, private developers and building owners are required by local ordinances to provide specified minimum levels of bike parking both within and adjacent to their buildings [4]. Beside the large number of bike racks throughout these cities, the most visible and innovative aspect of bike parking policy is the provision of state-of-the-art parking facilities at train stations. For example, there exists a modern 'bike station' adjacent to the city of Muenster's main train station, it offers secure, indoor parking for 3300 bikes as well as bicycle sale, repairs and washing. The station has direct access to all train platforms [6].

5.1.3 Modified intersection

Separated bikeways and cycle lanes protect cyclists from being exposed to traffic dangers between intersections, however they can pose safety problems when crossing intersections [6]. There were specific designs modifications at intersections in order to avoid that conflict between motor vehicles and cyclists, and although these design measures vary from city to city but they generally include many of the following [14], [15], [4] :

- Special cyclist-activated traffic lights are used.
- High visible and distinguished colored bike lane and crossings at intersections.
- All turns allowed for cyclists while special turn restrictions for cars.
- Insertion of traffic islands and bollards in streets to sharpen turning radius of cars, and thus force them to slow down when turning right.
- Advance green traffic signals for cyclists and extra green signal phases for cyclists at intersections with heavy cycling volumes.
- Special bike lanes leading up to the intersection, with advance stop lines for cyclists, far from waiting cars.
- Realigning bike pathways a bit further away from their parallel streets when they approach intersections, to avoid collisions with turning cars.

5.1.4 Integration with public transport

The cycling in most Dutch, Danish and German cities is integrated with public transport. They recognize the key role of cycling that plays as a feeder and distributor service for public transport. Bike parking is provided at train stations in the city center as well as at outlying stations along the rail network [16], it is possible to take bikes on trains and trams with extra fees. Also, parking facilities are provided at major bus terminals, bus stops and bus routes interchanges. Bike-and-ride facilities at bus stops are not as extensive, secure and comfortable as those at rail stations, but they help offset the lack of bike racks on buses. Another form of bike-transit integration is the provision of bike rentals at every major Dutch, Danish and German train station and many suburban stations as well [17], [6]. and bikes can be left at any specified location throughout the city instead of being returned back to the point of origin.

5.1.5 Traffic calming approach

This approach is made up of three main categories to achieve traffic calmed zones; first category is the traffic calming measures, these are some modifications to the streets themselves, such as road narrowing, raised intersections and crosswalks, traffic circles, extra curves and zigzag routes, speed humps and artificial dead ends so that to provide a space for cyclists. The Dutch, Danish and German cities have traffic-calmed most streets in residential neighborhoods, reducing the legal speed limit to 30km/hr and often prohibiting any through traffic [13], [18]. The most advanced form of traffic calming _the "Woonerf" or "home zone"_ imposes even more restrictions, requiring cars to travel at walking speed. The second category is the car-free zones, the Dutch, Danish and German cities had created extensive car-free zones in their centers, mainly intended for pedestrian use but permitting cycling during off-peak hours [14], [19]. Some Dutch cities introduce bike lanes and cycling facilities such as parking in car free zones [4].The combination of traffic calming measures in residential streets and prohibition of cars in city centers makes it virtually impossible in some cities for cars to intersect the city center to get to the other side. Cars are forced to take various routes instead, thus mitigating the congestion, pollution and safety problems they would cause in dense city centers. The third category is the Bike street, it has been adopted in these countries, especially in Dutch and German cities. They are narrow streets where cyclists are given absolute traffic priority over the entire width of the street. On normal case, cyclists are usually expected to keep as far to the pavement (or lane of parked cars) as possible, so as not to interfere with the motorized vehicles. However, on Bicycle Street, cyclists can ride anywhere they want. Cars are permitted to use the streets as well, but they are limited to 30km/hr and must yield to cyclists and give special consideration to avoid endangering them [6].

6. 'Al Zamalek' neighbourhood; Introduction

This is one of the important selected neighborhoods located in the west of Cairo, an island connected with other parts of Cairo through three major bridges. In the first quarter of the 20th century the land uses include deluxe housing, embassies, foreigners related facilities, public parks, sport and social clubs, nowadays it comprises landmarks and famous destinations, the area consists of a number of palaces owned by the royal family that played an important role in encouraging rich people and politicians to build characterized houses which featured the identity of the island. In addition to the high standard of living of its residents, the area comprises most embassies in Cairo; it attracted people of different nationalities and cultures to live in.

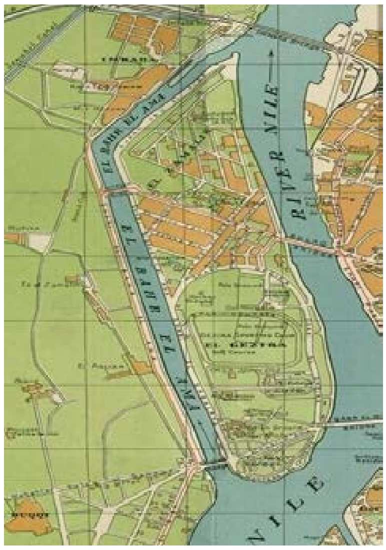

Fig. 1 The location of 'Al zamalek' Island

Fig. 2 'Al Zamalek' 1933

6.1 Urban and transport history of 'Al Zamalek'

During the 12th century, an island appeared between in the river Nile in Cairo. In 1372 another island one appeared, they formed 'Al Zamalek' during the 17th century, this was a Turkish name means the fishermen houses which surrounded 'Mohamed Ali' Pasha palace. The first building occurred in the island was 'Mohamed Ali' palace in the year 1830, followed by 'Al Jazera' palace in 1869 by 'Khedewy Ismail' which hosted 'Empress Eugenie', it is now the 'Marriot' Hotel. In the beginning of the 20th century, major buildings were built in the island, 'Al Zamalek' palace and a planning of a park took place in the south, horse race track in the north part of the island which characterized by its agricultural lands. The only transport mode between 'Al Zamalek' and 'Beau lac' was the small boats, 'Khedewy Ismail' built the first bridge 'Qasr Al Nil' bridge in 1869, then 'Beau Lac Abou Alea' bridge in 1908 by 'Khedewy Abbas Helmy the second' which was dismantled in 1998 to build the new 'Al Zamalek' bridge.

6.2 Streets related problems

The streets in 'Al Zamalek' are classified into three streets' types _as in most streets of Cairo_ primary streets that hold high traffic volume such as '26th of July' street, secondary streets that connect the primary streets with local ones, and local streets that transfer movement to primary and collective paths. 'Al Zamalek' is cut by a primary route which is '26th of July' street, covered by '15th of May' bridge, the street reaches a width of 18 meters, two ways consist of two lanes each. The rest of the street is occupied by car parking under the bridge perpendicular on the street direction. The streets in are better that many other streets in the city center, however, they are having problems as most of the streets in the city of Cairo, mainly the crowding problem, these include;

The decreased number of parking places which lead to the usage of parts of the streets as parking areas parallel to the pavement, and waiting takes place as infractions, the width of some streets is not enough but only for one car to pass through, high traffic density in the main streets such as '26th of July' street and the presence of traffic nodes at street's intersections are major problems, the streets are classified according to directions; they have all one direction except '26th of July' street. However, this classification is not based on actual usage of density of movement along these streets, the occupation of sellers and cafes to the pavements, even to the cars' paths, in addition to the electricity kiosks that occurred at the middle of the pavements, all these are obstacles to pedestrians, the existence of a large number of public facilities and services especially the educational ones such as schools and colleges in 'Al Zamalek' created crowded zones which reflected on the streets especially in rush hours, the interference between pedestrians and cars movement in the streets because of the pavement occupation, people move down street anywhere, also the pedestrians crossings are existed but only in '26th of July' street with its intersection with other collective streets. However, pedestrians do not cross the streets from these points as well, the deficiency of the infrastructure in most locations affects the movement such as water leaking down streets or lacking suitable rain drainage, the presence of garbage despite the high standard of living of the residents, the garbage spread down many streets.

6.3 Strength issues of 'Al Zamalek' to accommodate cycling

The area has a number of strengths that encourage cycling, the spreading of trees in the neighborhood especially those of old ages, streets are shaded in most parts along their paths, and some are totally shaded which represents a good environment for cycling. The streets are relatively short except for the major routes '26th July' street and 'The nil' street. Narrowed streets in this district force cars to drive slowly, this helps promoting cycling. There are a number of stopping points where there spread bus stops that represent a good stop and communicating points along the paths. There are markets, services and shops in the area. The 'Nile' street represents a very important route in the area and it is characterized by the presence of the river Nile which is an attractive focal point for movement along and for stopping to enjoy passing through. 'Al Zamalek' is characterized by the presence of a number of sights that characterizes the neighborhood, these represent attractive points for movement and characterized marks when passing through streets and recognizing the paths. The area comprises different building types and styles, some represent historical ages. These types of buildings are preferred to segregate from vehicle movement where deterioration can take place because of traffic pollution. There are a large number of schools in the area, this represent an important factor to encourage students to cycling through their daily journey to and from the school inside 'Al Zamalek' area and the following neighborhood if the student lives outside the area. The high educational and cultural of residents would represent an opportunity to increase the awareness of the importance of cycling as a transport mode; this will lead to the ease of spreading of this mode if bikeways and related facilities are existed. Many foreigners live in this area due to the existence of their home countries' embassies in the same place, this leads to the existence of different cultures, some of them aware of the importance of cycling and others use bikes in their daily journey in their own counties, which in turn would make it easier to apply such a mode.

7. The Plan for promoting cycling in the studied case

An action plan is proposed in order to promote cycling in this neighborhood, from the analysis of data; the area has a number of strengths that can be used successfully to reach a plan for cycling. With the involving of each of the Government, planners and people a set of strategies from the three cases could be deducted to promote cycling in 'Al Zamalek'. The Action plan should include at first statement of problems and opportunities, this covers the reviewing of context, summarizing issues, reviewing community issues and community observations and review problems. Second, making of community map which shall complete the base map and preparing typologies. These two stages to complete the analysis process then third, the plan for implementation will be put down, the plan consists of six stages, the first one is to decide actions, the problem should be identified, the proposed solution and the methods. The second one is to gather prioritized actions, which actions would take place now, soon and later. The third step is to identify tasks, for example implementation of parking spaces, the tasks will include studying of all available parking areas, people's density, calculation of required parking areas and locations. The fourth step is to consider implementation, for example, raising awareness of the importance of equivalent clean transport mode, the reflection on public health, putting rules and looking for funding. The fifth step is considering responsibilities, the people, the Government and planners. Then finally synthesizing proposal, this includes the tasks, period of time, responsibility, result and cost.

A set of policies can be deducted from the strategies of the Netherlands, Denmark and Germany, and take place with the involving of Government, planners and people in the studied area in Cairo. The Government has to change traffic laws and regulations to avoid motorists from being a risk to cyclists, the existence of cyclists down the street should be supported by traffic laws and also to avoid disorder in streets. With the application of car use restrictions such as limited speeds, directions and pedestrianized areas, the streets will be safe for cycling. Advanced stop lines and traffic signals priority for cyclists should be available. Planners have to study the residents' transport needs, separate cycling paths can be implemented with accompanied all related facilities and bike parking throughout the neighborhood. Coordination with other public transport could be achieved and bike rentals locations should be planned at specific locations. Traffic calming measures should be applied to the streets to provide a proper space and safety for cyclists, in addition to the provision of traffic signals for cyclists at intersection of streets giving them the priority for crossing with the installation of bollards along bike routes. The community has a role in spreading the awareness of the necessity of cycling as a clean, healthy and cheap mode of transport, training for cycling should take place among all people especially the young ones at school age. As a model, Dutch, Danish and German children receive training in safe and effective cycling techniques as part of their school curriculum. Therefore, comprehensive cycling training courses should be available for all school children as a start. In addition, training of motorists should take place to respect pedestrians and cyclists and avoid hitting them. A priority status should be existed to non-motorists that forces motorists to drive with special attention.

8. Results

Cities' streets need an environmental-friendly mode; cycling is an easy, clean and cheap, it is a major mode of transport in the pioneer countries, Germany, Denmark and the Netherlands. This successful result is reached in these countries because of a clear plan includes both of cycling related design measures and government policies. Also people are aware that cycling is good for health and the surrounded environment, regardless of their gender, income, age and purpose to travel.

9. Discussion

The set of design measures previously illustrated is important to achieve convenient as well as safe cycling in the city streets. This affects cycling directly and promotes people to use bicycles on their trips. So, it is essential to refer to these measures in the designing process besides to another government policies that encourage cycling indirectly.

It is recommended to provide a number of cycling related activities, these activities stimulate interest in cycling. Promoting cycling through policies and design measures make it a safe mode of transport and a convenient one with all the available facilities, however, promoting cycling approach should have an attractive issue in order to bring interest for people to cycle. Some of the following promotional measures are used by six cities in the Netherlands, Denmark and Germany:
. Access to bikes, through free use of city bikes parked throughout the city, 'Park and Bike', discount bike rentals for motorists who park their cars and bike for the rest of the journey, easy, convenient and inexpensive bike rentals at train stations and throughout the city, and company bikes loaned for free to employees who can use them during the day for short business trips.
. Bike trip planning, through comprehensive bike maps for most cities, cycling websites with extensive information for cyclists on bicycling routes, activities, special programs, health benefits of cycling, bikes and bike accessories, etc., and internet bike trip planning tool allows finding the most comfortable or quickest route to the specific preferences and needs of each person.
. Public awareness, annual bicycling festivals and car-free days that promote the environmental advantages of bicycling and display the latest bike models and accessories, besides a wide range of cycling competitions for different ages and skill levels.
. Public participation in bike planning, regular surveys of cyclists to assess their satisfaction with cycling facilities and programs and to gather specific suggestions for improvement, bike councils that provide a platform for opinion exchange among stakeholders from businesses, the bike industry, the city administration, research institutes, universities, and bike experts.
Traffic education and cycling training should be applied especially for young age ones, comprehensive cycling training courses for all school children, special cycling training test tracks for children in specified locations, special fun programs and traffic education for motorists to respect pedestrians and cyclists and avoid hitting them.

10. Conclusions

The most important issue in making cycling an important means of transport in the three pioneer countries is making it safe and convenient through designing separate cycling paths and lanes along busy streets, in addition to all related facilities and services such as bike paths network, bike parking, traffic calming measures, well designed intersections and integration with public transport. Therefore three main objectives should be concerned when starting planning to implement cycling in cities; these issues are safety, convenience and attractiveness, they should be fulfilled within cycling travel networks. Also, the combination of both the government policies and the cycling design measures results in encouraging cycling and helped in making it safe, convenient and attractive in these three pioneer countries. The restrictions of car use is important to encourage cycling, however, the provision of cycling facilities and parking is important to promote cycling as well in the city of Cairo, this includes bikeways and all related services. Implementation of cycling in Cairo streets could take place in a number of chosen neighborhoods as a start, based on a good study of all urban and population related analysis and survey. The main problem facing people in streets is the interference between pedestrians and motor vehicles beside the unplanned transport network. This represents risk and difficulty for cyclists. On the other hand, if well planned, cycling has a good chance to take place down the streets since it is considered an easy and cheap mode for most people in Cairo, suitable for the majority of low income people and because of the crowded streets, it will be faster than any other mode especially in short trips.

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Rehabilitation of Public and Semi-Public Space of Housing Estates: the Case of Lubartow

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Summary

Demographic trends, changes of lifestyle, stricter technical and safety requirements towards infrastructure of housing estates, and natural wear and tear make the existing housing environment from the times of mass housing projects fail to meet current standards. To select value-adding modernization measures, the planner should base on a thorough investigation of needs and requirements. The paper presents a case study of rehabilitation of areas between housing blocks of a nineteen-sixties estate in a small town in south-eastern Poland. The scheme was inspired by a research project – an inhabitant's opinion survey. Improvement guidelines derived from this survey were used in constructing an operating plan for the town district, incorporated into the town's operating plan, and finally won EU grant. The quality of the space is exceptional – and the project can serve as a template for similar schemes in other locations. One of the main success factors was empowering inhabitants to take decisions on the function and form of their living environment. User satisfaction monitoring helps maintain the users' interest in the development of their neighbourhood.

Keywords: Built environment rehabilitation, public spaces, user involvement, opinion survey

1. Introduction

Revitalisation projects are mostly associated with complex activities that concern large areas such as whole districts of cities or entire housing estates. They combine coordinated modernisation and refurbishment of built assets, and measures taken to influence human attitudes and behaviours with the aim to enhance social infrastructure and economic growth of the neighbourhoods. Areas subject to revitalisation do not need to be already dilapidated or dysfunctional. Revitalisation is meant to counteract observed or even expected unwelcome trends such as depopulation or deterioration of buildings and infrastructure, as it is more economical to prevent than to cure. Typically, areas that need attention are defined by three types of problems: population drop and aging visible in changes of household structure; wear and tear, and obsolescence of the facilities and buildings; unstable economic environment causing local unemployment and collapse of businesses. Adaptation to changes of lifestyles, ageing, migration, as well as general trends towards energy efficiency and safety of the built environment reflected in stricter building codes make the existing building stock functionally deficient. The built environment ceases to answer contemporary requirements while still being in good repair. This is the case of many housing estates built in the nineteen-sixties to nineteen-eighties, so in the times of industrialized construction, large scale housing projects, and mass production of uniform blocks of flats. In Poland, this type of housing stock seems generally not as problematic as in other European countries [1, 2]. The buildings are not decrepit; the estates have not become ghettos of welfare-dependent people. Due to a general shortage of affordable housing, depopulation in such estates is not a serious threat yet. However, with the availability of better housing options for those wealthier or more industrious, growing labour mobility, and dropping population, the unwelcome trends become visible, especially in smaller towns. To prevent these thends from developing further, one can take actions to increase value of housing assets. These actions cannot be limited to technical intervention into the buildings, as the whole living environment needs to be considered. One of the most important aspects is understanding what people want – as inhabitants of this environment, they may have a different view than urban planners, architects, or facility managers.

The paper presents a case study – a project in a small town located in south-eastern Poland, conducted in 2014-2015 by the Lubartow Housing Cooperative in one of estates under its management. Its objective was to improve public and semi-public spaces around the housing blocks. The project was inspired by the findings of a research project that involved, among others, an inhabitant's opinion survey conducted repeatedly in prefab housing estates throughout Poland, including the estate in Lubartow. Findings of the survey were used in constructing an operating plan for the town district and incorporated into the town's operating plan that was awarded a EU funding. Though the project was relatively small, the quality of the space justifies presenting it as a template for similar projects in other locations. The success factors were: empowering the inhabitants to decide on the shape of the neighbourhood, and the determination of the cooperative's management in convincing the local government on the importance of the project.

2. Methodology

2.1 Case study research

The case study research is defined as empirical inquiry to investigate a contemporary phenomenon within its real-life context, when the boundaries between phenomenon itself and its context are not clearly evident, and in which multiple sources of evidence are used [3]. Case study approach facilitates understanding of complex issues, recording and sharing experience gained in a limited number of events, allowing for unique sets of conditions and their relationships [4]. The method proved useful in social sciences [5] and has been adopted to built environment research [4, 6, 7]. It is also a standard approach for recording knowledge in project management [8, 9, 10]. The steps in the case study research comprise [11] defining objectives of the research and plan the case study (includes selection of the case) setting procedures of data collection, collecting evidence, analysing collected information, and reporting.

2.2 Purpose and plan of research

The case study of a project in Lubartow was an element of a broader research project on defining a general methodology for setting a framework for revitalisation projects dedicated to housing estates with precast concrete buildings erected between 1960 and 1990. The guidelines for preparing such projects were to be juxtaposed with the practice of modernization projects taken by the facility managers. The guidelines for revitalisation projects comprise seven steps described in Table 1, and serve as a framework of presenting the case study project in the sections to follow.

Table 1: Seven steps to define revitalisation project (by A. Ostanska)

Step No.	Aim	Description
1	Define current state of assets and the neighbourhood	Analyse archival documents, building inspection records, records on energy performance; check crime records; inspect assets to supplement input
2	Listen to what the users say and raise their interest in improvement possibilities	Conduct opinion surveys (direct interviews) on the quality of living space and problems in the neighbourhood, on “wants and needs” and willingness to participate
3	Summarize findings, define problems and find support to fight them	Look for funding possibilities (e.g. Regional Operational Programmes) and assure they can be accessed
4	Define aims and objectives	Define aims and priorities in cooperation with all parties; keep users informed and involved.
5	Call up an interdisciplinary design team	Refine proposals providing feasibility studies, prepare designs; keep users informed and involved.
6	Call up an interdisciplinary implementation team	Supervise implementation, assure quality and accountability; keep users informed and involved.
7	Call up an interdisciplinary team to monitor effects	Keep track of the social, technical, environmental, economic etc. effects. Conduct periodic user opinion surveys, follow crime statistics, observe user behaviour; gather input for planning new projects; keep users informed and involved.

As a revitalisation is an interdisciplinary process, the first steps are devoted to a thorough investigation of the estate’s current state. The revitalisation, in the context of this paper, is a preventive measure, and its aim is to satisfy current users. Therefore, an emphasis is put on referring to the users’ opinion (examined by means of an opinion survey) and keeping them involved at least in the decision making process, if not in the physical implementation of the project. The project is aimed at future benefits, thus its effects need to be monitored. One of the tools proposed for this purpose is a periodic interdisciplinary opinion survey among the inhabitants.

2.3 Selection of the case

The case of the Lubartow Housing Cooperative’s project was particularly suitable as the object of research. Firstly, the estate was a typical example of prefab housing – with typical estate layout (scattered development, large open-access areas), deficiencies due to wear and tear and obsolescence of assets, and problems faced by a residential quarter of a small town of weakening economy – so in need of intervention. Secondly, the project preparation phase was just underway with all information readily available. Thirdly, the estate managers have shown exceptional initiative (compared to what had been observed in other estates throughout Poland) to exploit external funding opportunities.

2.4 Procedure of data collection

The methods of the case study data collection were: analysis of documents provided by the housing estate managers (feasibility study, designs, building maintenance records etc.), analysis of the local revitalisation programme, direct observation by a structural engineer, interviews with the housing estate managers, and a user opinion survey conducted in 2010 (during preparation of the revitalisation project's feasibility study). The estate managers welcomed the research project as the results were to be immediately shared with them and potentially used to supplement their input for revitalisation plans. Therefore, the research team was offered access to the estate's technical records and the revitalisation project documents. The aim of the interdisciplinary opinion survey was to learn about the users' views on deficiencies in the neighbourhood and the ideas on how to fight them, to make them aware of possibilities of improvements, and to estimate their willingness to get involved in the measures for improving their living conditions. Another aim was to compare the users' views with the view of the project team. The best method was decided to be a direct interview based on a questionnaire with a variety of closed- and open-ended questions [12]. The questionnaire was used before to collect input from other prefabricated housing estates, so its form had been verified in practice [13], and survey results could be compared with data from other locations across Poland. The survey was agreed with the estate management and publicly announced. The interviewees, visited at their homes, were made aware of the purpose of the survey. One adult person per flat was asked to give answers. To avoid bias, so to approach a representative sample of inhabitants, the interviewers visited the estate several times, at different times of the day.

3. Results

3.1 Analysis of the project documents

3.1.1 Project background

Lubartow is a town of 22,000 inhabitants located in south-eastern Poland, 25 km north of the largest city of Lublin voivodship. The town is rich in historic monuments, though its character was changed by the development after WW2. The town's industry, strong before the nineteen-eighties, did not survive economic transformation and despite some industry still present in the area, employment and business options are not rich.

The area revitalised in the course of the project in question is an estate of housing blocks located on the brink of the town conservation area (area 3 in Figure 1) and neighbouring with other housing quarters of prefabricated blocks and individual detached houses (area 5 in Figure 1). Initially, as the rest of prefabricated housing areas of the town, it was not considered by the revitalisation programme established by 2006, its potential future inclusion conditioned by social problems reaching "more serious levels", and on the project's eligibility for public funding (Town Council decision No. XLIII/322/06). Structural Funds 2007-2013 provided no support for modernising this type of assets. However, a further development of the municipal revitalisation programme for the years 2009-2015 covered the entire town. The town was divided into five zones according to their character. The housing areas (including prefab estates) were considered for revitalisation as social problems evolved to unacceptable levels, the energy performance of the buildings was considered inadequate, and degradation of infrastructure was observed.

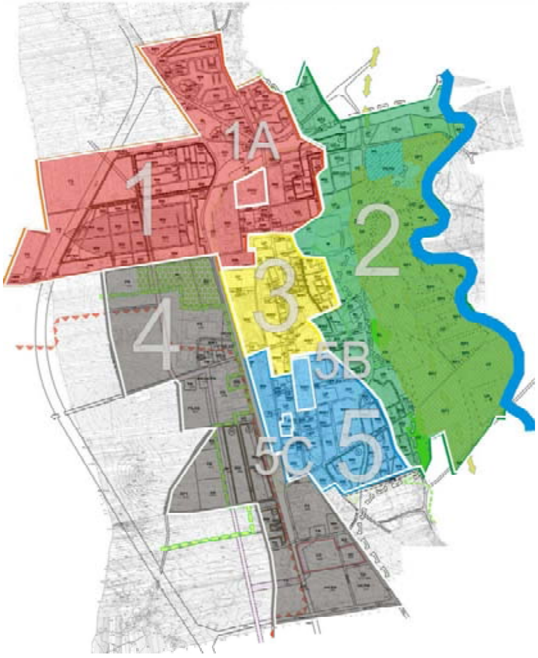

Fig. 1. Lubartow revitalisation zones: 1-Residential area, 2-Greens, 3- Historic town centre, includes the object of the case study, 4-Industrial zone, 5-Residential area. Source: Local Revitalisation Programme 2009-2015 Annex, Town Council Decision No XLIX/312/10.

3.1.2 Definition of the current state of assets and the neighbourhood

The state of the area in question can be summarized in the form of SWOT matrix (Table 2) based on the project's feasibility study. The weaknesses were confirmed by the building's maintenance records and direct observation.

Table 2: SWOT matrix abbreviated from the project's feasibility study.

Strengths	Weaknesses
Good location (historic and functional town centre), Well developed transport network, Availability of local amenities, Well working public services and infrastructure (waste management, access to gas grid, high quality water supply, sewage system, district heating system), Covered by up-to-date comprehensive land use plan, Zone of local tax relief for investors.	Growing unemployment rates, vandalism, alcohol problems,aging Low standard of blocks, aesthetic deficiencies Low energy performance of buildings, Obsolete systems: heating, water supply, electrical, Roofs in bad condition, no vestibules, Obsolete power grid in the area, Backlog of unpaid rents, irregular payments, User sense of insecurity in the area & no monitoring system, Unkempt greens and dilapidated public space infrastructure, No attractive and safe playgrounds, No cycle routes to other parts of the town, Architectural barriers, Not enough street lighting, Not enough parking space, No sports and recreation infrastructure, High prices of flats,

	Obsolete road infrastructure, not adjusted to current fire protection standards and traffic.
Opportunities	Threats
Availability of public funding for modernization projects (Regional Operational Programme), Public support for business start-ups, Proximity of a big city (25 km), Big investment in road infrastructure and environment protection in the region, Availability of funds for fighting social exclusion, Good education, health, social welfare infrastructure, Availability of public support for non-government organisations.	Formal barriers for infrastructure investment (legal system) Growing costs of construction materials and services, Quickly growing road traffic, Limited potential of the local police forces, Wrong behaviour patterns in the media (growing aggression and egoism), indifference towards socially inacceptable behaviours, Growing maintenance costs of expanding infrastructure, Bad vistas for employment rates, Growing energy prices.

3.1.3 Opinion surveys

The community of the town of Lubartow eagerly refers to modern media to discuss local affairs. There exist several Internet services dedicated solely to local news, two traditional local newspapers, and two local cable TV channels. One of them is run by the analysed housing cooperative, providing, among others, live transmissions on the meetings of the local authorities. Thus, the project stakeholders were well informed of any modernization initiatives. The housing cooperative conducted its own opinion survey among the inhabitants of its assets in 2009. The results were used for preparing modernization project proposals and to provide arguments for the project’s being included in the revitalisation programme. They were cited in the Local Revitalisation Plan for Lubartow. The results of the independent user opinion survey conducted by the authors in November 2010 on what was considered to be worth doing was fully convergent to what was planned and delivered, which confirms that the user voice was well heard.

3.1.4 Finding support

Investigation into the condition of the area in question provided the planners with arguments to include this area in the Regional Operational Programme for the Voivodship as, this time, the programme offered financial support to cooperatives. The precondition was that the projects were included into municipal revitalisation programmes and/or municipal plans for low-carbon economy. The scope of problems the project was to address was in accordance with both of them; thus the estate area was accepted as a location covered by the Local Revitalisation Programme of the Town of Lubartow for the years 2009-2015. This did not happen automatically. With considerable effort, the managers of the estate convinced the local government that it is worth to invest in these areas now - before the problems of infrastructural and functional obsolescence of these relatively modern areas become urgent and spoil effects of revitalisation of the neighbouring historic town centre. The project to modernize prefabricated estates was given a high priority in the revitalisation programme and considerable financial support (Local Revitalisation Plan for Lubartow – Town Council Decision No XXXVI/226/09 and XLIX/312/10). Finally, 70% of the project budget was a public grant.

3.1.5 Definition of project's aims, objectives and scope

As comes from the project's feasibility study, the revitalisation project was divided into two stages. One was modernization of public spaces and playgrounds. The other was devoted to improving energy performance of buildings and refurbishing access roads to adapt the area to contemporary fire protection requirements. The products of both stages are listed below to give the overview of what has been done in the estate's area of nearly 5 hectares:

1. Insulated envelope of 5 multifamily blocks,
2. Painted staircases of 8 multifamily blocks,
3. Refurbished access roads (for vehicle and pedestrian traffic), 800 m,
4. Refurbished and expanded parking areas, 1600 m^2,
5. Modernized / new children playground, outdoor gym, sheltered meeting point, 2200 m^2,
6. New/refreshed lawns, planted trees and shrubs, 22400 m^2,
7. Newly built cycle road connecting two cross-town routes, 150 m,
8. CCTV monitoring system with underground ducts,
9. Wheelchair ramps providing access to all buildings,
10. Street lighting powered by solar panels,
11. Modernized access road to comply to modern fire protection regulations, 4163 m^2,
12. Modernized playing field (synthetic turf),
13. New vestibules to all multifamily blocks to reduce heat loss.

3.1.6 Call up an interdisciplinary design and implementation teams

In the analyzed case, the design was ordered by engineering specialists, and the design process was not coordinated by an architect. However, with detailed functional specification prepared by the investor, the relatively small scale, low complexity of the project, and its technical character, narrowing the design team to representatives of few disciplines proved sufficient.

3.1.7 Call up an interdisciplinary team to monitor effects

Feedback collection is necessary to assess the effects of the project. Monitoring energy bills helps assess efficiency of thermal modernization measures, direct observation of recreation and sports infrastructure usage is needed to check if money was well invested. These tasks are obvious; however, a periodic user opinion survey would provide a supplement to direct observation. It would allow the estate managers to detect inhabitant needs that have not been met so far, or to detect new problems. The managers of the estate have not resorted to post-project opinion surveys yet.

3.2 Results of the opinion survey

The opinion survey was conducted by the authors in November 2010, just as the decision was taken to include the project in the town's revitalisation programme. At this point of time, the project was in preparation, and results of survey, apart from being used in the research projects, could be directly applied to refining the project's scope. Selected results of the survey are presented in Figure 2.

The questions concerned, among others, overall satisfaction with living conditions and deficiencies in the infrastructure and amenities. The results indicated that most inhabitants (66%) positively assessed their flats, buildings and living environment. However, many found the equipment of public and semi-public spaces inadequate (not enough parking spaces, not enough places to sit, facilities for actively spending time outside the buildings worn, underequipped or missing. Thus, the spacious areas between buildings, planned lavishly compared with today's standards, were practically unused: to spend time outdoor, the inhabitants were heading to other parts of the town. The surrounding was generally reported to be unattractive. The frequency of answers (Figure 2) gives insight into the users' priorities of measures worth taking to improve the outdoor environment. Interestingly, almost one third of interviewees declared that they would be glad to contribute their work for free to the improvements.

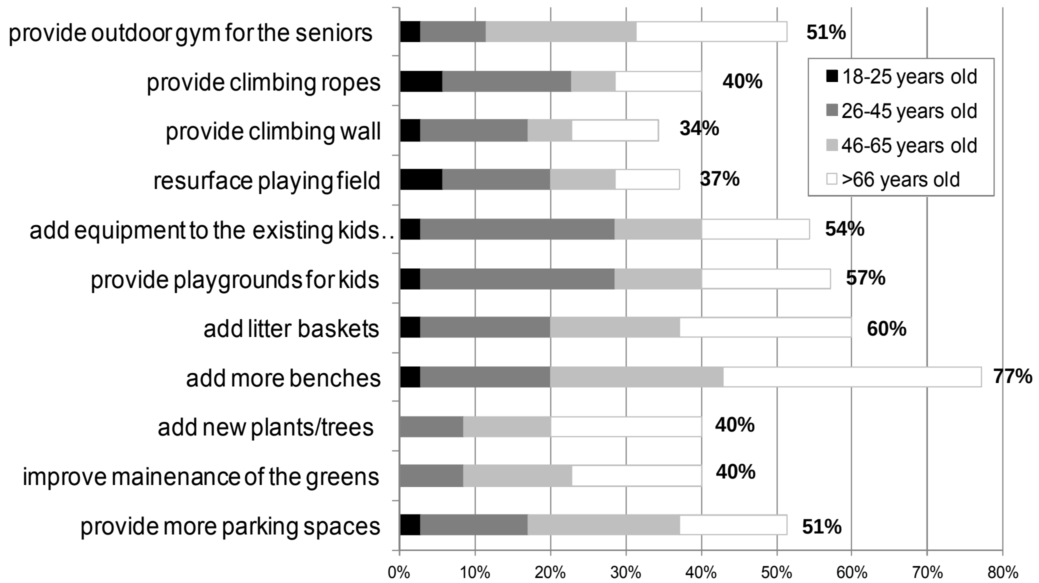

Fig. 2. User postulates for equipping outdoor space (selected results)

4. Discussion

The project of adapting the assets to current building codes could have been defined solely by architects and city planners. Thus, a success in reaching technical objectives such as elimination of architectural barriers, enhancing thermal properties of buildings, changing parameters of road infrastructure to serve increased traffic and modern fire apparatus access, might have been achieved with no regard to the opinions of the inhabitants. However, revitalisation projects are not aimed only at enhancing parameters of physical assets. They are aimed at improving satisfaction of living conditions, stopping unwelcome trends in social life, creating opportunities for local economic growth – and the measures for that must be tailored to the case and needs of local people. Therefore, these needs must be defined. The simplest way to do that is ask questions and listen to answers. Care should be taken to make people aware of what is being made and why, and if the effects are to last – to make them become involved in revitalisation activities. This can be achieved by empowering users to decide on their surroundings. The case study project was in large extent defined by the users: the managers of the housing estate, so the direct investors, took care for that. They understood that a project that technically consists in providing infrastructure can succeed only if this infrastructure is useful and actually used. They provided what people said they want. Post-project observations by the authors of the paper indicate that the new infrastructure becomes an element of local life: people sit on the benches in the refurbished estate greens, children play in the safe playing grounds until late evening, more and more people use bicycles to travel to work using new cycle route, teenagers play football in the sports field instead of just "hanging around". It may be too early to announce a success, as the infrastructure is open to the public for one year, but improvement is visible.

Regarding the wider perspective, so the town revitalisation programme, actions taken by the local government in cooperation with local stakeholders are justified. Making the whole town a revitalisation area seems a wise decision. Technical measures can be taken in isolated areas and bring good effect. However, with such small communities, fighting social exclusion or improving satisfaction of living conditions cannot succeed if they are limited to a particular town quarter. Determination of the housing cooperative management led to including the estate into the local revitalisation programme which gave access to funding normally unavailable to such relatively new areas. Considering the project location, if the stakeholders failed to give the project a high priority, the "flagship project" of the revitalisation programme (the revitalisation of the town's conservation area) could fail: the contrast between a newly refurbished old town and the neglected "prefab intrusions" would be too great.

The project was possible only with some public grant. The estate managers were aware that, with the backlog of unpaid rents and worsening economic situation of the town, they would not collect enough funds for works on this scale, so they grabbed the opportunity of using Regional Operating Programme as soon as it arose. A simple calculation shows the scale of the funding gap: the project cost was PLN 6,650,570. The grant was over 70% of this sum. If the whole sum was to come from the cooperative repair and modernization fund (PLN 1.20 per square meter of flat per month payable with the rent – increasing it would be opposed by the cooperative members, its collection would take 13 years (552 flats, average flat area is 45 m^2), ignoring inflation. The opinion survey conducted by the authors pointed to the fact that some inhabitants would be willing to pay more towards improvements, but these unbinding declarations were made only by 26% of interviewees, and the amounts were relatively low (PLN 500 a year declared by 23% of interviewees, and PLN 1000 a year declared by 3%). Counting only for this money would mean that the amount equal to the grant would be collected for 58 years. The opinion survey conducted by the authors in the project preparation phase indicated also that some inhabitants of the estate would be willing to contribute their work to improvement activities (29% of the interviewees would offer help for free). This potential has not been discovered in the survey by the estate managers, and no traces of considering such contribution are visible in the local revitalisation programme. It would be advisable to use it for the sake of integration of the community. Polish examples of such direct physical participation projects to improve surrounding of the residential buildings can be found in many locations (e.g. in Szczecin [14] and Warszawa [15]), but they usually refer to small backyards (semi-private and semi-public spaces) in densely developed town centres, and not to large open-access areas. The authors' independent post-project survey, conducted in 2014 showed that the inhabitants of the estate are satisfied with the project outcomes. They also become aware of and interested in other possibilities of improving their environment. For instance, they declare support for investment in environmentally-friendly systems, especially if these cut energy or water bills. The surveys can thus become a springboard to planning new improvements and searching for funds.

5. Conclusion

As supported by the evidence from the case study, interdisciplinary surveys of user opinions provide a valuable input for defining user needs towards functions of their living environment. The analysed – unique in Polish conditions – example indicates that the relatively modern housing estates can be subject to revitalisation processes to prevent unwelcome trends in the neighbourhoods before they grow to serious problems, and that public funding for such projects becomes available. The effects of revitalisation measures need to be monitored, and a useful tool in this process may be periodical opinion surveys. Conclusions drawn from such surveys supplemented by conclusions from asset inspection are likely to provide directions for further projects.

6. Acknowledgements

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Renewable Energy and Thermal Comfort in Buildings as Smart Grid Components

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Summary

This paper presents results of a research and demonstration project which is set up to avoid grid instability in electrical supply. It is a contribution to protection of the climate and environment as one of the global goals of sustainability.
The central idea of the experiment is to store and shift stochastic load peaks of electricity caused by wind turbine generation in a highly efficient building, in order to extend the sustainability of the building supply.
The process chain starting from electrical power generation, electrical grid control down to the occupational use of energy is covered. Electrical energy is stored with Power-to-Heat technology controlled by the supplier.
A signal based on measured loads of a wind turbine and another signal based on grid and market characteristics have been the indicators to simulate the realistic operation of fluctuating renewable energy fed into the grid.

Keywords: Renewable Energy, Smart Grid, Power-To-Heat, Thermal Comfort

1. Introduction

In Germany the “Energiewende” serves as goal to shift energy production from non-renewable resources to renewable. A significant amount of the electric power consumption shall be met by power from wind turbines and photovoltaic plants. Although the peak generation load roughly meets the overall consumption in Germany, no conventional power generation plant could be taken off the grid. Due to the highly stochastic energy fed from wind and photovoltaic generation the need of control increases dramatically. One of the reasons is the high amplitudes and load peaks of power fed into the electricity grid of wind power generation. In the winter the amount of power consumption increases. During that period it should be considered that the warranted minimum power is roughly zero [1].

Buildings, and their supply components, must be integrated into smart grid concepts. Energy storage in tanks for domestic hot water, heating or direct control of heat pumps are technologies to cut load peaks. The different approaches of electricity grid control and heating control for thermal comfort in buildings, and their interaction to activate storage potentials, have not been well investigated yet.

2. Demonstration Project for Sustainable Use and Control of Power from Renewable Energies

The idea of the presented experiment is driven by the aim to control the balance of the electricity grid by using the heating of the building by the energy supplier. The balance of the so called residual load shall meet the inflexible feeding into the grid with variable loads especially in times of high wind power generation. In the optimal way, heating should be only used at wind load peak as excess power. In that way the experiment joins the two technical systems electricity grid and building to an interaction by activating a negative load control using the power-to-heat concept.

3.1 Terms

3.1.1 Smart Grid

“A smart grid is an electricity network that can efficiently integrate the behaviour and actions of all users connected to it — generators, consumers and generator/consumers — in order to ensure an economically efficient, sustainable power system with low losses and a high quality and security of supply and safety.” [2]

The supplier controls the load with targeted power requests and integrates it into the electricity grid as a storage component.

3.1.2 Demand Side Management

Demand Side Management is defined as targeted power request in general. [3]

In the first period of the experiment this system has been used. The operational behaviour of the system could be derived by analysing the measurement results of the first two years. Based on that data, the loads could be planned.

3.1.3 Demand Response Management

Demand Response Management is a short time and planned load shift as a reaction to market signals (market prices) or a reserve capacities. Market prices or power requests are caused by extreme events in the energy sector. [3]

3.1.4 Functional Electricity Storage

Functional electricity storage systems achieve temporal or spatial compensation in the energy balance, between consumption and feeding in with load shift in the profiles.
All time or spatial shifts within the load profiles, with the aim of compensations within the balance, can be defined as functional electricity storage. A functional storage can be assigned the same properties as pure power storage systems, e.g. capacity, degree of efficiency […]. [4]

Table 1: Key data of the experimental building

Energy Reference Area	Volume	A/V	Airtightness	Overall Energy Use January	Overall Energy Use Annual	Specific Energy Use
			n_{50}	ø (2009-2011)	ø (2009-2011)	ø (2009-2011)
[m²]	[m³]	[-]	[1/h]	[kWh]	[kWh]	[kWh/(m²a)]
301	1.291	0,6	< 0,3	1.247	4.191	13,9

3.2 Passive House

The direct use of power to heat buildings could lead to arguments about a waste of energy. To avoid this, the energy has been stored in a very efficient building: a passive house.
Passive houses are highly efficient buildings. This term defines a technical building standard. It is verified by a balance under steady state conditions with the Passive House Planning Package. The primary energy demand of such is Q_p<= 120 kWh/(m² a), the space heating demand must not exceed 15kWh/(m² a) or a peak demand of 10 W/m² [5]. The chosen experimental building had been built following these criteria. Further significant key data can be taken from table 1.

Voss has shown in 1997 that such a highly efficient building can be independent from a profile of a generation load [6]. The only additional requirement is a large scale heat storage tank. Because of the delayed heat loss the passive house is flexible for stochastic heating events.

In order to keep the costs of the experiment as low as possible additional capital investments have been made. For this purpose the construction and the concrete core system have been used as the heat storage tank. The interface for heat is the stratified water storage tank on-site that temporarily stores the heat before distribution into the concrete core.

4. Description of the Experiment

The experiment has been set up to demonstrate the potentials of buildings in smart grid systems.
The complete process chain has been established: starting from power generation to electricity grid control and finally energy consumption in the building. The storage system is a non-electric power storage using Power-To-Heat-Technology. The general structure of the experiment is shown in fig. 1. It showcases the flow of electric power and information. In the building the components of the heating system are shown. This describes the order of the energy flow: starting from the instantaneous water heater with the smart grid control unit flows through the stratified storage tank to the concrete core system. All is embedded by the airtight and the highly insulated building envelope. The solar thermal system has been put out of operation for duration of the experiment.

4.1 Entire Process Chain

The experiment starts at the wind generation plant „WKA Einsiedel“. That is integrated in the grid area of the project partner and network provider LEW AG. The load profile of the wind turbine is monitored from the transmission control centre in Augsburg. Using algorithms of the network supplier two control signals are generated. They are titled „wind signal“ and „market signal“ within the experiment.

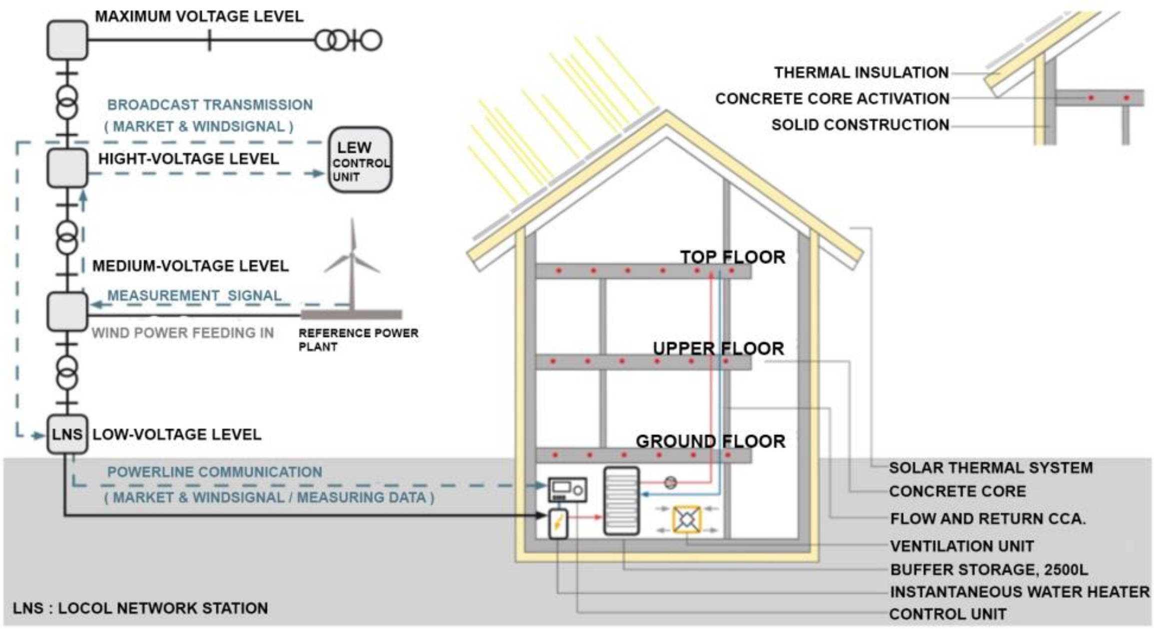

Fig. 1 Experimental setup

4.1.1 Wind Signal

The signal, based on measured loads of the wind turbine, represents grid aspects („wind signal"). It covers highly fluctuating feeding in into the electrical grid, due to the stochastic generation.
The load profile is the measured load from the Wind turbine "Einsiedel" in Bavaria. A load over one MW activates the signal. Below 20 kW generation load ends the signal within the hysteresis. This range is adjusted to the frequency of building supply systems on-site.

4.1.2 Market Signal

The second control signal is defined as „market signal". It is used only to store energy in the stratified storage tank. This is in the interest of the network supplier. It has been activated by a PV-feeding in the electrical grid by a load more than 300 MW and a consumption load below 1600 MW in the distribution network. This signal is only activated at loads below 20 kW of the wind turbine.
The market signal covers roughly the current market conditions of the spot prices in Leipzig. During noon PV-feeding in is high, and consumption loads decrease. This leads approximately to lower average market prices.

The signals are transmitted to the local network station. There the signals are transferred with internet-technology using power line communication. The signals are sent to the building via the household utility connection. With the enabling signal the instantaneous water heater is controlled as then energy conversion unit. The heat is stored in the stratified storage tank as the heat interface. Depending on the signals of the network provider, the heat can distributed and stored in the concrete core heating system.

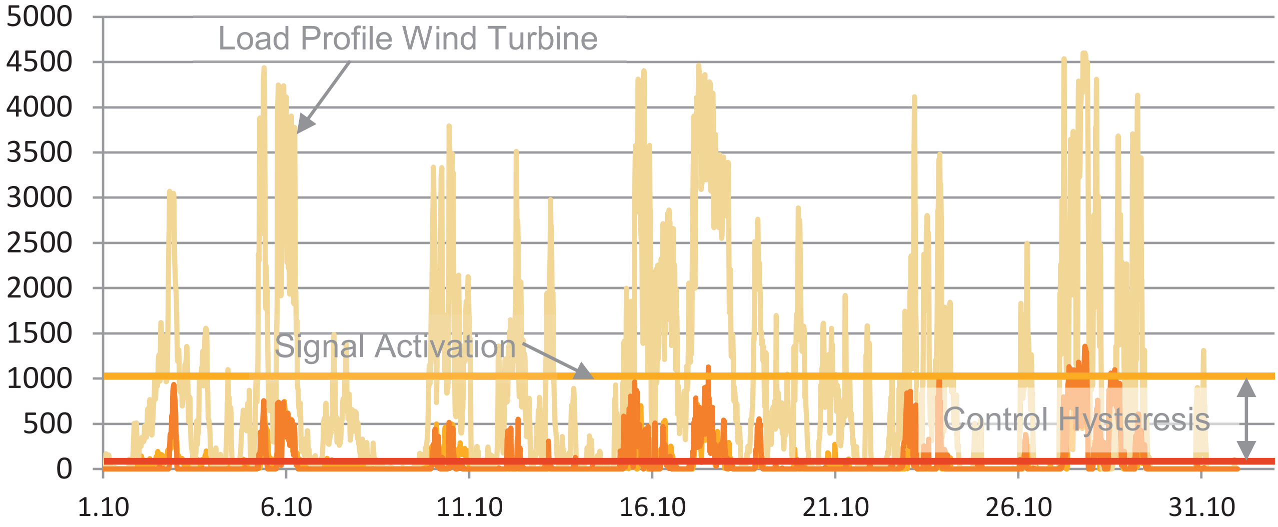

Fig. 2 Characteristic Loads from the Wind Turbine (October 2013)

4.2 Control Signals

The control signals are based on the operational knowledge of the network supplier and project partner. The algorithms derive from daily distribution network control. They are pragmatically set up for direct application in practice.

Klein et al. [7] has already investigated the basic correlations between indicators for grid control but on a more general. The pragmatically selected parameters of the presented experiment just cover roughly the same results as the paper.

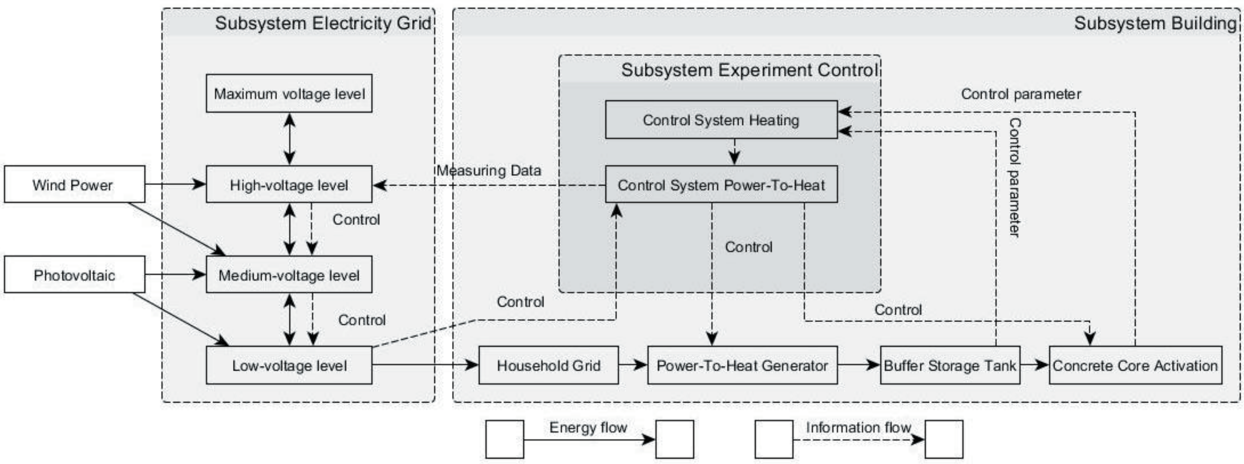

Fig. 3 Overall System of the Experiment, Energy, Control and Information Flows

5. Experiment Results

The average of heat per day could be estimated as 51 kWh /d (=3406 kWh / 67d). The power based on the wind signal covered about 2136 kWh or 32 kWh /d (=2136 kWh/67 d).
During the experiment, the heating control was always operating at the upper limit of the predefined temperature corridor. This is the result of the reduced cooling and energy flow from the passive house. Previously published prototype results stated that 500 kWh could be stored [8] during one heating event. In practical application it was found that only a percentage of the 500 kWh was achieved, as result of stochastic system loading. Therefore, it can be inferred, that such a type of building is not suitable to cover such maximum heating events. Instead, this type of building can be used for load shift and secondary storage in electrical grids.

Table 2: Heat storage and consumption during the experiment period (09.12.2013-14.02.2014)

Wind signal [kWh]	Market signal [kWh]	Power Conventional [kWh]	**Overall Energy [kWh]**
2.126	320	744	**3.190**
67%	10%	23%	**100%**

5.1 Dependencies between Thermal Comfort and Stochastic Heat Storage

The target temperature for heating has been set to T_0 = 22°C. To activate the storage potential of the construction a temperature increase of ΔT = 2 K was set as control boundary in coordination with the occupants. The resulting temperature corridor was used only in the test phases during the initial commissioning.

At the beginning of the operational phase of the experiment, the building has been loaded up to the maximum temperature. Meanwhile, additional stochastic loads caused by solar Radiation led to an additional increase in temperature of 1,9°C. In addition to the daily operation the stochastic signals (mainly wind signals) occurred. Therefore, the cooling phase lasted primarily only a few hours. The maximum time between two signals has been six days (29.12.2013 – 04.01.2014). The heating system works well in all experimental phases and signals gaps with low variations in temperature. Due to mild temperatures in winter and the frequency of the occurrence of the signals, the room temperature´s range has been only ΔT = 1 K from 23,6°C to 24,6°C. Despite stochastic loads, the system is functioning like standard heating.

5.2 Dynamic Processes

The dynamic of the mutual interaction between random solar radiation and stochastic signals from experiment can be seen in fig. 6: The interval from one wind event to the next is six days. During that period, the building gets its heat from solar radiation as well as internal loads. The market signals received during this time can only be used to deliver energy to domestic hot water.

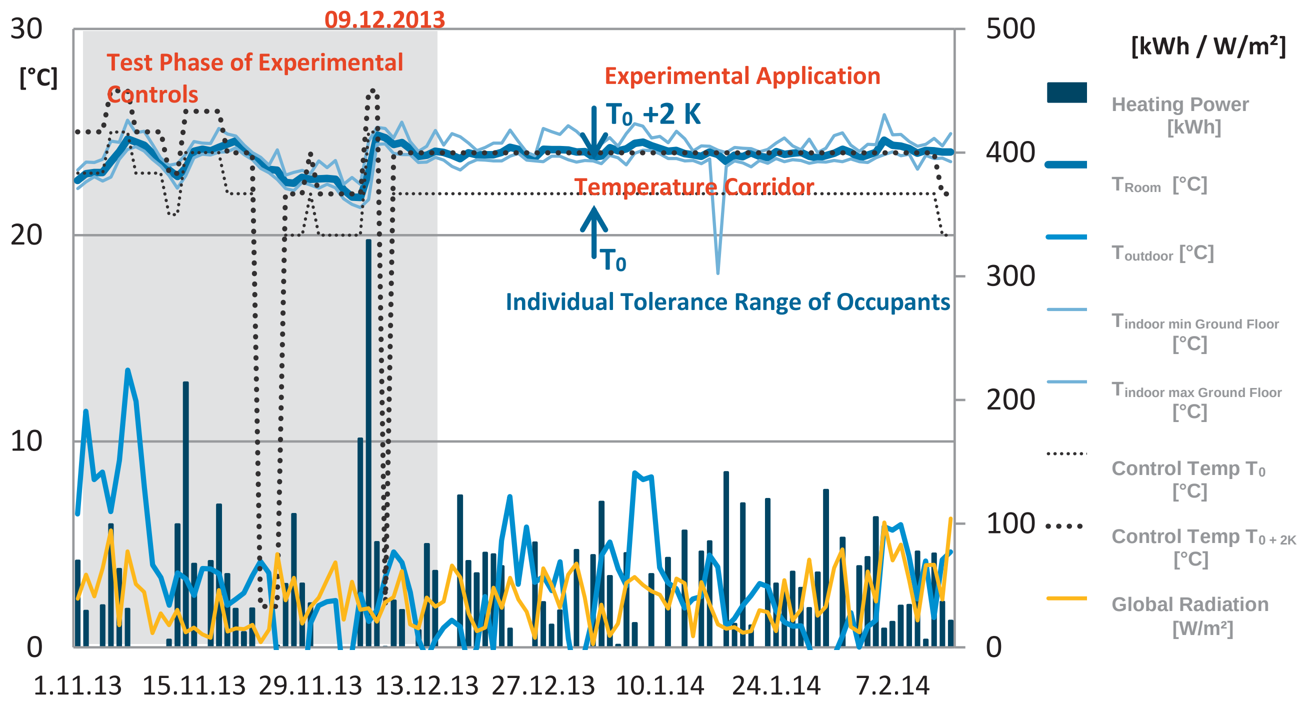

Fig. 5 Test Phase and Supplier Controlled Application during the Period of Measurement

The temperatures in occupational zones reduce ΔT = 0,3 K from 24,2 °C to 23,8 °C. The decrease of temperatures is delayed by significant distribution losses. Without that effect, the reduction is estimated to be 0,6 – 0,8 K in this period.

5.3 Heat Inertia of the Passive House

The indoor temperature is significantly influenced by (global) solar radiation. This causes daily temperature variation of ΔT = 1,2 K. The designed temperature corridor is, therefore, almost entirely used up by solar loads. This can be explained by the large heat inertia of the building and the capacity for short term heat storage. In critical situations the solar load and the power storage can be superposed.

Following DIN EN ISO 7730 the reference values of the operative temperatures are taken to classify the daily temperature variations. The comfort categories from the standard are taken for offices or school buildings. The measured temperature is only a reference temperature to the heat control unit. The operational temperature can only be roughly estimated. For correct comfort evaluation more factors must be considered.

The discharge curve at the end of the experiment shows the mutual interaction of the building and the environment. It is a random sample within the period (fig.7). The building was not heated from 12.02.2014 to 06.03.2014.

The mean exterior temperature has been 4,9°C during this period. The indoor temperature decreases from 24 °C (13.02) to 21,9 °C (05.03) within 22 days. The result is an average of 0,1 K temperature reduction per day. The maximum decrease of temperature has been only 0,4 K/d and the maximum increase has been measured by 0,2 K/d. Over a six day period an increase of temperature have been measured without heating. The mean indoor temperature has been 23,0 °C.

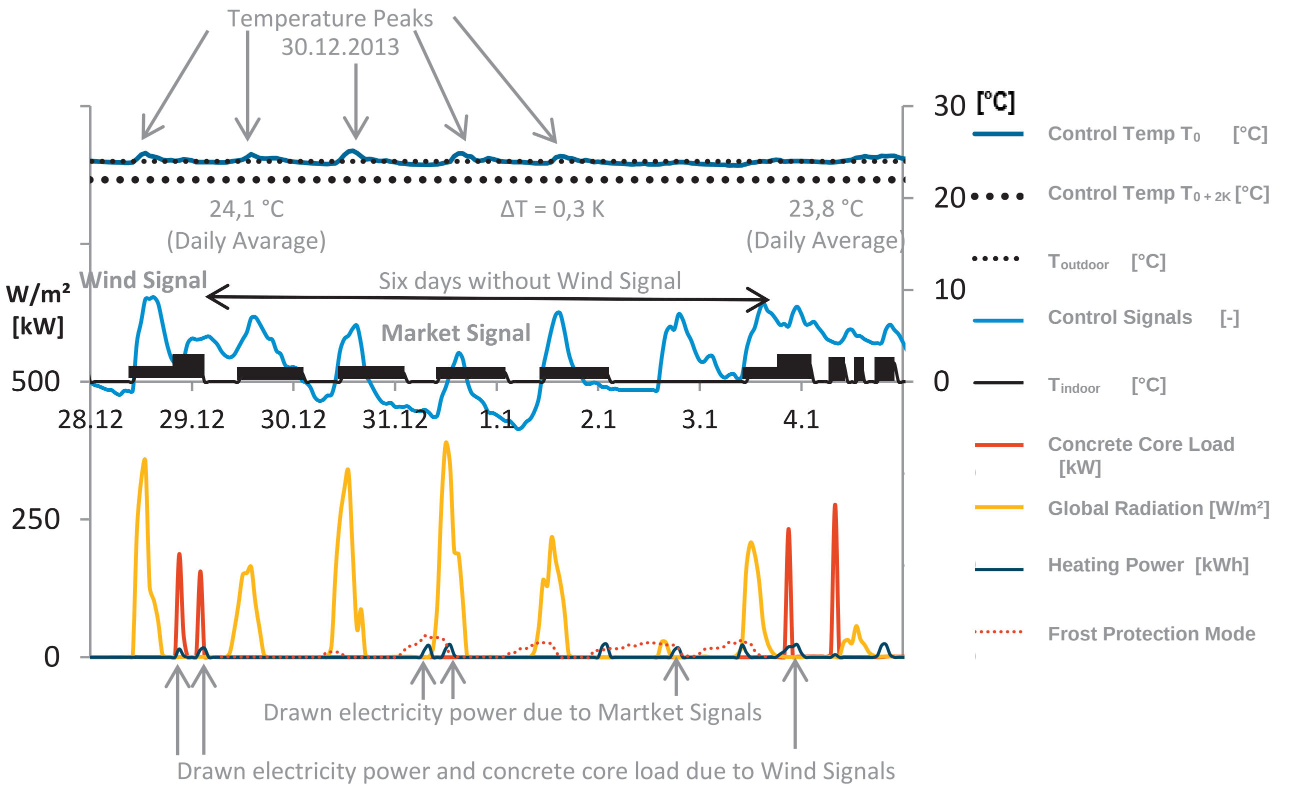

Fig. 6 Dynamic System Behaviour of Building, Environmental Energy and Experiment Processes

The special thermal properties of the building lead to very low heating load. During the period described above the heat load is fully covered by solar and internal loads. It is apparent that heat can only be stored if the indoor comfort is accepted with some limitations by the occupants.

Furthermore, occupants comfort is not occupants' acceptance. It has been found as a side effect that building owner is very dissatisfied if they lose the ability to control the building, even though they had the ability to do so. It has to be concluded that the temperature corridor always has to be open for change in addition to the indoor temperature control.

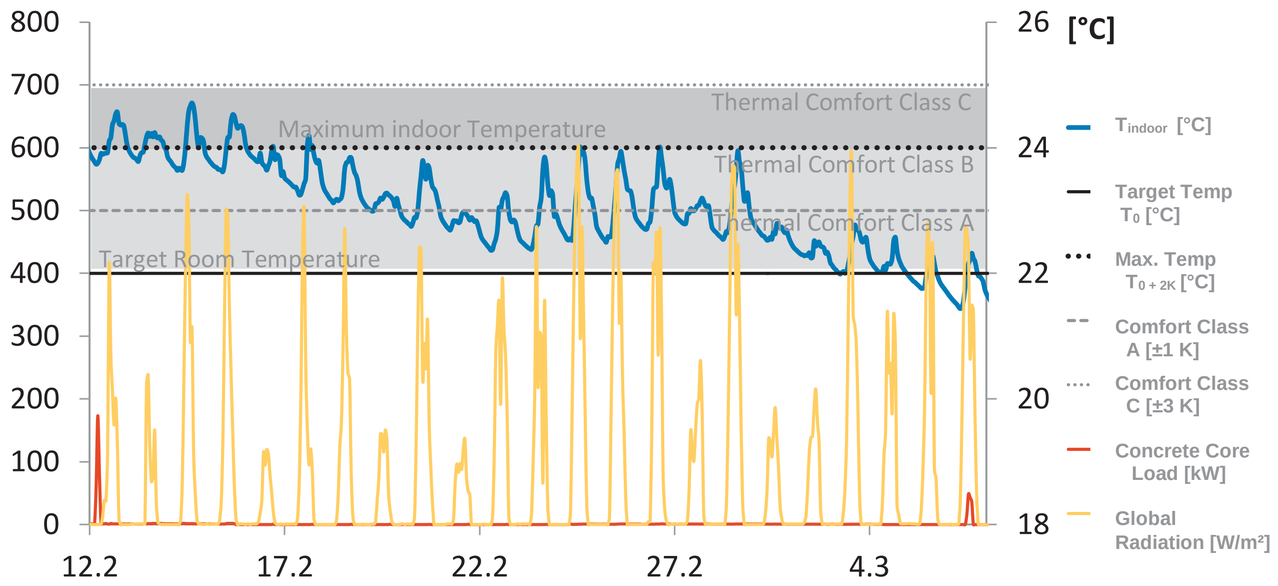

Fig 7 Cooling Phase of the Building during the Experiment in Relation to the Comfort Categories.

6. Discussion

The developed system of the presented project shows a regular heating system under stochastic loads. The observed characteristic of the heating is similar to conventional heating systems because of the dampening effects of construction. The system can directly be integrated where concrete core systems are part of the supply. The heating control must only be adapted to the control algorithms and the internet communication technologies. It is a very low cost system.

It has to be considered that the presented storage system can only be achieved if opposing goals are compensated:

- Minimizing the energy consumption reduces the storage potential of the supplier.
- Maximizing energy efficiency reduces the annual period to apply the storage system. It is the opposite of a constantly addressable storage system.
- To fill the building with energy increases the distribution losses. The use of the stratified tank as interface has led to very high temperatures. Poorly insulated pipes resulted in 30% distribution losses, and unfavourably affected the experiment.

6.1 Flexible Heat Storage and Power Market

A combination of energy efficient passive buildings and control from network suppliers provide many possibilities for flexible functional storage. The approach of the experiment had been to store a maximum load from the beginning of the given signal. These insights offer a bundle of control strategies to discharge electric distribution networks using the Power-To-Heat concept. The suggestions are flexible control strategies as shown in fig. 8. The building reacts as a storage system with response to cover high peaks respectively the complete signal duration. For more flexibility the controls should be able to vary the drawn load on request.

7. Conclusion and further work

7.1 Occupants acceptance

To explore the potentials of building structure it is necessary to share an additional temperature corridor. That must enclose occupant’s individual habits. A minimum temperature corridor (0,5 K) is accepted and does not disturb thermal comfort. Human perception is unaware of these variations. To extend the range additional incentives have to be offered. It can be observed as critical reaction if occupants feel loss of control. A control which can be modified any time could lead to acceptance. To promote the ecological factor of additionally drawn energy from renewable resources, the occupant could be supported by financial incentives.

7.2 Definition of the term excess power

Most important is the political definition of excess power. The price for household electricity (29,81 Ct/kWh) is around four times higher than common heat (6,78 Ct/kWh) (destatis).

The high price of electrical energy derives from the expansion of renewable energies. There is no definition of excess load to offer attractive prices for households to provide storage and participate in network control. There must be a significantly reduced price offered to households that accept energy loads which stabilise the electricity grid.

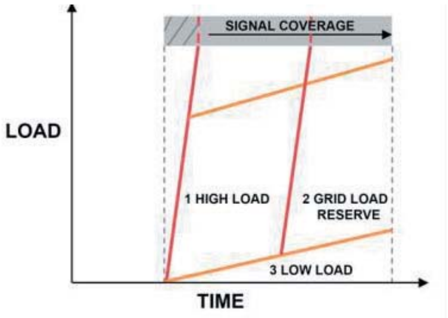

Fig. 8 Load control for better load coverage

8. Acknowledgements

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Research on Innovation Development for Residential Real Estate Investment Projects

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Summary

Technological and business innovations have a strong impact on the global goods and services market. Thus, innovation development in real estate sector cannot be attributed as a self-going process. This development is regarded as the consequence of number of causes identified as internal and external environment factors.

While seeking to maintain competitive advantage real estate companies integrate the innovation issues within the development of new residential projects from the conceptual design stage. This paper presents the theoretical innovation development model for real estate investment projects including all stages of project life cycle.

The practical part of the research is based on investment alternatives analysis of a new and modern low-rise residential real estate development project with well-developed infrastructure. The expert evaluation revealed the following priority order of criteria for innovation development in residential real estate project: profitability index, risk of investment, usage of alternative energy sources, technological innovation level and internal rate of return. Effectiveness of different innovative alternatives was evaluated by applying multi-criteria decision making methods.

Keywords: innovation, investment project, effectiveness evaluation, multi-criteria decision making

1. Introduction

Current environmental regulations and energy policy in European housebuilding industry have put pressure on businesses to innovate while delivering sustainable construction. Although these frameworks for high-energy efficiency in new housing contribute significantly to the adoption and managing innovations in the construction and real estate sectors, however the level of innovations usage in these sectors has been reported low without any positive tendency for improving their performance in the near future [1].

Numerous different models of innovation have emerged over the past half a century. There are many definitions of innovation with different perspectives and applications, however, we can broadly define innovation as “an idea, practice or object that is perceived as new by an individual or other unit of adoption” [2]. Existing theories relating to innovation are diverse with different definitions focussing on the various kinds of innovation that exist. Trott [3] claims that there are seven various types of innovation, including product innovation, process innovation, organisational innovation, management innovation, production innovation, commercial/marketing innovation and service innovation. It is essential for an organisation to identify the types of innovation needed for company success, although, in many cases all of these innovations work in conjunction [4]. Innovation is not only essential for corporate success but is also commonly viewed as extremely important for business survival and growth of an organisation's core strengths. Therefore, in order to realise the potential benefits from innovation, strategies for its management need to be in place and aligned with business strategy [5].

Despite the many models of innovation in the literature, quite few studies have been conducted in the field of innovations in the construction and real estate sectors. The main issue, addressing adoption of innovations in buildings, is that buildings are comparatively complex and constructed in a specific social context within temporary alliances with various stakeholders through the different phases of construction process. Innovations in the construction and real estate sector are not usually implemented by one stakeholder but rather within the property development project. There are limited literature materials, which focused on the assessment of innovation efficiency particularly in the context of investment project and its delivery. Some discussions that are related to profitability of innovation implementation in residential real estate are only mentioned but not extensively reviewed in accordance with the scope of the research.

2. Methodology

Our research adopts a comprehensive literature review from numerous published sources. Consequently, in this section we will review some of the earlier literature on innovation challenges relevant for this study. Delivered literature review rationalized and consolidated five main streams of research related to the innovativeness of the construction and real estate industry; service innovations in Facility Management; practice of managing innovation in housebuilding organisations; the role of different stakeholders in driving innovation in the sector and technological innovations and sustainability in construction and real estate industry.

The first stream of research designates the innovativeness of the construction and real estate industry in relation to the industry's specific characteristics. Numerous papers present enhanced approach to identify innovative construction and real estate companies, define the extent of adopted innovation and explore the factors that drive and challenge innovation in the sector [6-11]. The increasing competition within the construction and real estate market has created a growing demand for innovations adoption as an essential factor for the competitiveness improvement. Serpell and Alvarez [7] highlighted that the innovators are typically construction companies with high levels of profitability. They also identified six major innovation drivers that are important for construction companies such as the culture and human capital, organizational structure, technology, research and development, partnering and knowledge management. The critical barriers that make innovation in construction and real estate industry very difficult are the culture and human management practices. The innovation barriers can also be differentiated into external and internal barriers within categories across multiple levels of analysis: external environment, organization, group, and individual [12]. At the same time, the concept of innovation in the construction and real estate industry is closely related with aspects of knowledge creation for efficient product design and delivery. Building information modelling (BIM) is considered as one of the most significant cultural and technological innovations, embracing the processes of design, construction and facilities management [13-15].

Innovations in Facility Management (FM) are considered as second direction of research on the innovations in the construction and real estate industry, represented by numerous studies of service innovations [5, 16-17]. The objectives of these studies were to investigate innovation in the facility management (FM) sector and identify the factors that affect the service innovation in FM services. Noor and Pitt [5] stated that particular barriers to innovation in services are intangibility, simultaneity and heterogeneity. They also concluded that the role of innovation in FM services is not just to deliver innovative solutions, but also to establish and develop a creative environment for comprehension, development and implementation of these solutions.

Studies of managing innovation in housebuilding organisations constitute the third stream of research on innovation. The complexity of the residential real estate industry presents challenges that resist the adoption of innovative products; therefore, housebuilding organisations have been reported reluctant to innovate [1, 18-19]. These studies provide for opportunities to eliminate barriers that prevent housebuilding organisations from engaging in innovation processes geared to highly energy-efficient housing. While reviewing the technological innovations in housing sector Pan [1] highlighted a wide range of factors centred on technical feasibility, commercial viability, market and statutory acceptance, supply chain competency and business risks, such as project risk, market risk and planning risk. Project risk is associated with uncertainties faced in managing the progress and control of costs across one or more development projects. Market risks are introduced by evaluating the commercial viability of development project without knowing the market conditions at the point of sale. Planning risk encompasses planning permission duration variability and the risk that future planning requirements may devalue the development [20].

The next stream is represented by the research that discusses the actual and potential role of different stakeholders in driving innovation in the construction and real estate sector [21-24]. Loosemore, Richard [21] confirmed in their study the important leadership role that clients provide in valuing and driving innovation in the industry. They also argued that most of clients were not open to innovation or prepared to pay for it, which also showed that lowest price remains the dominant selection criterion in tenders. Some studies define the developers or builders as key players in this industry’s notable resistance to innovation. The developer resistance to innovation is associated with split of benefits from innovation adoption among different stakeholders. While benefits are mostly perceived by occupants, developers have minor interest in making such investment. The lack of financial funds constitutes an innovation barrier linked to investors, not providing sufficient monetary means, as well as lack of financial resources on the organizational level. This research on financial constraints highlighted how external and internal financing are related and resist innovation in buildings [12].

The last stream of research is related with technological innovations and sustainability in construction and real estate industry. Some studies investigate the impact of environmental policy instruments on technological innovations aiming to improve energy efficiency in buildings [25-27]; and others provide a critical review of existing green real estate developments [28-29]. By 2020 all buildings will need to have sustainability ratings, while new developments will need to be sustainable in the broadest sense. Technological innovation, in particular, could play a large role in reducing the energy consumption of buildings. Highly energy-efficient housing is receiving more and more attention in the literature on innovation, tending to focus on individual technologies and/or general sectoral innovation challenges. Green innovations, including the innovations in technologies that are involved in energy-saving, pollution-prevention, waste recycling, green product designs or corporate environmental management, can enhance the product value, and thus reimburse the costs of environmental investments. Furthermore, the technologies behind smart appliances, smart building management systems and integrated distribution management systems are continually becoming more advanced and affordable.

The move towards greater sustainability in building design presents opportunities and risks for real estate asset managers and developers [30]. Innovation in the construction and real estate industry is often classified as a cost-intensive investment with very indefinite returns due to the risks associated with significant variations in demand and profits. Furthermore, the innovations within the sector are constrained by complex value chains and project-based operations. Specific innovation management systems such as idea generation methods, funding systems and project management methods are considered as having solid impact on the performance of innovation and innovative ideas. Besides, the identification of management criteria, which effectively distinguish between profitable and unprofitable new technologies, is essential for assessment of innovations in a wide variety of cases.

By taking into consideration the major sources of resistance to or acceptance of innovations in the real estate and construction industry broadly discussed in the scientific literature mentioned above, the authors of the paper developed the model that is recommended for evaluation of real estate investment project effectiveness due to adaptation of innovations during various stages of project life cycle (see Figure 1). The aim of the new theoretical model is to reveal systematic components affecting the development of new technologies and innovative ideas in construction projects as well as to evaluate the overall investment effectiveness of real estate development in the context of innovativeness. By using analytical framework based on the existing literature on various innovation concepts essential factors were identified that affect the successful creation or adoption of innovations in real estate and construction sector, embracing the processes of design, construction and facility management.

3. Results

Proposed innovation development for real estate investment model is applied to the case study of new residential development to determine optimal investment approach from the point of view of Real Estate Development Company. The case study investigates the selection of the most efficient innovative approach that provides the optimal ratio between the project innovativeness and risk of the investment. The case study is a hypothetical project of low-rise residential housing, which developer is a reliable real estate company, valued for sustainability and innovativeness.

The new development‘s territory covers 7 hectares. It is a new and modern low-rise settlement within the 12 km distance from the city centre, surrounded by the green park with well-developed infrastructure. Project consists of 29 low-rise residential buildings: 10 multi-apartment houses, 11 semi-detached and 6 individual houses. With a total space of 27900 square metres and a total capacity for 400 families it is expected to be one of the sustainable and innovative real estate development examples. Total project investments estimated 20 million EUR, of which 4 million EUR is paid for the land property. The investment is sponsored by the company’s equity (30 %) and the bank loan (70 %). The project creates revenue streams from the sales of apartments, semi-detached and individual houses. The expenses consist of design, construction, financing, sales and other costs. Applicable profit tax rate is 15 %.

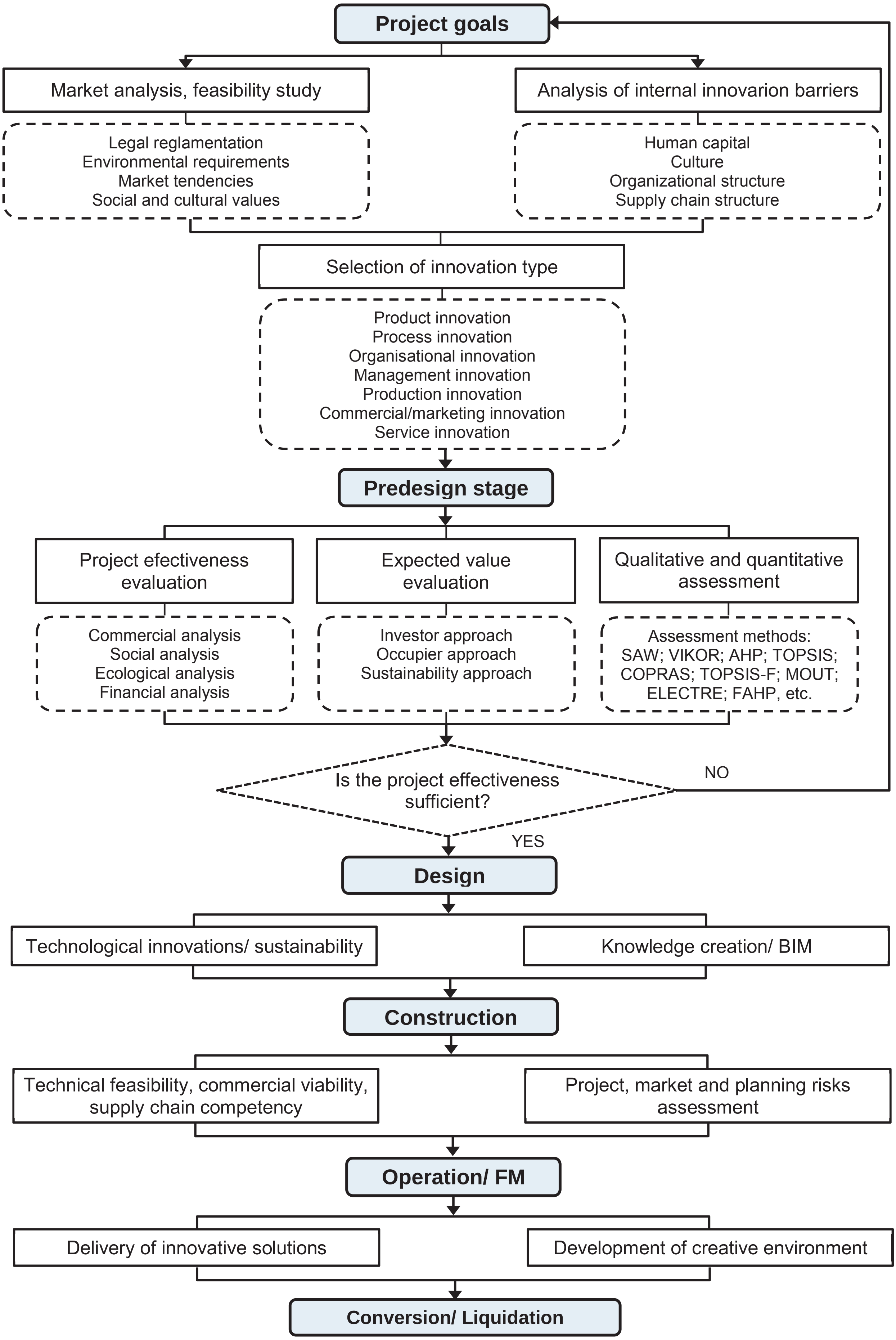

Fig. 1. Innovation development model for real estate investment projects

Innovative project approach by type is described in Table 1. All semi-detached, individual houses and apartments will be equipped with the intelligent building management system in order to allow residents save energy resources, raise the comfort level, to maximize the security. Depending on the selected options, there will be alternative renewable energy sources used as well as different complexity and functionality of intelligent building management system provided. The four alternatives were formed with further described options.

Table 1. Project innovative solutions

Innovative approach	Implementation of innovative solutions
Product innovations	- Solar energy for water heating. Geothermal heating system. - Intelligent building management system. - Snow melting system for pavements.
Process innovations	- Construction budget, timetable, human resource management by using special software.
Management innovations	- Remote collection of data from utility devices and statistical processing.
Service innovations	- Virtual project presentation for marketing purposes. The website with the entire district visualization. - Remote management of building service systems. Automatic data transfer.
Commercial innovations	- Residential area is being built not so far from the city centre; even so, the environment is formed in the way of the suburban surroundings.

Alternative A1 - intelligent building management system (heating and lighting control, security alarm integration) in residential buildings.
Heating system control. Different comfort temperature might be set in individual rooms by controlling the heating system. Individual heating scheduling (daily, weekly, day - night). Room temperature might be set by using Room Controller, PC and the Internet. *Interior lighting control.* It is remote possibility to turn on/off the light, regulate lighting intensity in rooms; control lighting according to predefined scenarios (for example, computerized lighting system uses scenarios simulating the presence of people at home when they are left away). The possibility to turn off all the lights by pressing one button when leaving the house, etc. *Security alarm integration.* When security alarm system is activated, the customized scenarios might be enabled: turning off the lights, electrical devices, reducing the room temperature. The users are informed about security alarm activation via SMS.

Alternative A2 - intelligent building management system (A1 listed functionality) and alternative renewable energy sources (solar collectors, geothermal heating) in residential buildings. Intelligent building management system includes residential space heating and lighting control and security alarm integration into a single management system.
Solar collectors. Solar collectors for hot water are installed on the roofs of the buildings. Due to that, the savings up to 65% of water heating costs are expected during the summer period. In case of insufficient amount of solar energy, hot water is heated up to the required temperature by gas boilers. *Geothermal heating.* All buildings are equipped with gas heating and with geothermal heating as alternative energy source in order to decrease the heating costs when the temperature outside is up to -10 degrees in Celsius scale.

Alternative A3 - intelligent building management system with maximum functionality. This is the expanded option of intelligent building management with additional functionalities.
Gas and water leak detection. Upon detection of gas/water leaks, the system informs the user, closes gas/water supply at the leak-site, and sends a warning message to the emergency services.
Automatic data collection from measuring devices. The system reads and transfers the meter readings to the data centre, which collects statistical data and provides its graphical presentation.
Electrical appliances control. Electrical appliances or groups of appliances can be turned on/off anytime in combining with user created scenarios. *Control of protective blinds.* By one push of a button all the blinds can be opened or closed. Control of protective blinds can be combined with other management systems scenarios, for example, system opens the blinds with the clock alarm or when the security alarm system is disabled.

Alternative A4 - alternative renewable energy and intelligent building management systems use not only in buildings, but also in all residential area.
Territory tracking. Residential area is monitored via video cameras; the main entrance is equipped with automatic barriers to ensure that strangers are not entering the territory of the development.
Melting snow from sidewalks. Ice and snow melting system installed on sidewalks ensures the safety of pedestrians. Temperature and humidity sensors react to changes in atmospheric conditions and provide optimum operation of snow melting system. *Remote control system*. All area's building service systems are monitored in real time. In the event of an emergency (water, gas leak or a power cut) in any room the message is transmitted to the remote control centre, where the automatically started the corresponding reacting systems. *Water, heat, electricity and gas readings are collected centrally.* The remote control system collects, processes data and provides a graphical analysis. Homeowners do not have to rewrite meter readings. *Solar collectors and geothermal energy.* All buildings are equipped with gas heating and with geothermal heating as alternative energy source.

Various advantages and disadvantages of each selected alternative can be identified from the developer's point of view. Based to the theoretical assumptions and the existing practice the potential alternatives for innovative residential development were implicated in the multiple criteria evaluation. For the evaluation of each innovation development strategy the following criteria were taken into consideration, including technological innovations C1, project risk C2, profitability index (PI) C3, renewable energy sources C4 and internal rate of return (IRR) C5. Initial data for multiple criteria decision making of innovation development problem was derived from the findings of the interviews with representatives of real estate development firms. Criteria, representing the investment efficiency, are calculated for the construction and sales period of 5 years with the discount rate of 5%. The criteria C1, C3, C4 and C5 are expected to reach their maximum values, while only C2 is targeted to minimum. The initial data for multiple criteria evaluation of alternatives is presented in Table 2.

Table 2.Initial data

Criteria	Dimensions	Optimization direction	Alternatives			
			A1	A2	A3	A4
Technological innovations	points	max	2	2	4	5
Project Risk	points	min	1	3	2	5
PI		max	1,198	1,197	1,203	1,209
Renewable energy	points	max	0	2	0	2
IRR		max	0,329	0,324	0,360	0,350

The subjective weights of the attributes were determined by using expert pairwise evaluation approach. Pairwise evaluation of the criteria provided by 10 experts is presented in Table 3.

Table 3.Subjective weights of criteria

	Criteria					Total
	C1	C2	C3	C4	C5	
Weight	0,165	0,165	0,290	0,235	0,145	1,00

Multicriteria analysis of selected alternatives was performed using TOPSIS method. By applying this approach, the efficiency of the alternatives has been determined and following priorities for the alternatives was obtained: A2, A4, A1, and A3. The calculation results are given in Table 4.

Table 4: Results obtained by applying TOPSIS approach

	Alternatives			
	A1	A2	A3	A4
Efficiency value, %	56	100	53	95
Priority order	3	1	4	2

The findings of study suggest the most efficient option for innovative residential development as Alternative A2 - intelligent building management system and alternative renewable energy sources (solar collectors, geothermal heating) in residential buildings.

4. Discussion

With time, definition of intelligent building has changed from purely technical to more user – oriented with their qualitative and quantitative performance measures pertaining to technical, functional, financial, environmental, and societal aspects [31]. Expected quantitative and qualitative performance scales for different types of built environments are specified by technical (health, safety, security), functional (functionality, efficiency, workflow), behavioural (social, psychological, cultural), and aesthetic performance criteria [32]. The new development is designed according to the principles of sustainability. Low-rise buildings do not dominate in the surroundings of green areas. Different types of housing (apartments, semi-detached and individual houses) create the community of people/families of different social background. High energy savings possibilities are provided due to projected A energy performance class of the buildings. Special attention is paid to the territory planning, by incorporating zones of car parking, playground areas for children, etc. Developed infrastructure for social life (close to the public transport, supermarket, businesses and services within the area) makes the project attractive for people who value quality life.

The innovative approach by implementing intelligent building management systems and alternative renewable energy resources is a challenge for project developer and different stakeholders. It makes impact on the suppliers and competitors as well as the customers by inviting them to make changes towards the innovative business environment. However, by analysing different scenarios of innovative approach, the conclusions can be made that the project innovativeness and risk of the investment first depends on the clients' preference to pay more for the comfort of their individual housing as well as for the future savings of energy costs. The developer takes his own risk to find the right time for the innovative project introduction to the market and to convince the customers to look for the best value for their money, considering the innovative approach.

5. Conclusion

The innovation development for real estate model developed by the authors incorporates the systematic components affecting the development of new technologies and innovative ideas in various stages of investment project life cycle as well as enables evaluating the overall investment effectiveness of real estate development in the context of innovativeness. This approach raises awareness amongst different stakeholders of investment project to justify the design, construction and operation solutions, while preparing the feasibility study of new real estate development.

Proposed innovation development for real estate model was verified by applying it to the case study of new residential development to determine optimal investment approach from the point of view of real estate development company. Priority ranking results of four innovation development alternatives approved the proposed approach of real estate investment evaluation based on the project innovativeness aspects.

Assessment of new residential development revealed the most efficient residential housing development option in Lithuania, adopting intelligent building management system and alternative renewable energy sources; whilst the analysis disclosed that innovativeness of investment project effects significantly developer's risk on investment.

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Resilient Community Centers for Nepal Earthquake Victims

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Summary:

On April 25 and May 12, 2015 two massive earthquakes devastated Nepal destroying nearly 700,000 homes and leaving over 2 million people homeless. In response a group of students and faculty from the University of New Mexico's engineering, economics and architecture departments formed UNM4Nepal. In collaboration with the UNM's Nepal Study Center, the Pratiman-Neema Memorial Foundation, the Lumbini Center for Sustainability, Kathmandu University, and Construction Management Technologies (Pvt.) Limited, UNM4Nepal developed the Himali Dream Partnership which is developing a sustainable Women's Community Center in the Nepali village of Bahunipati. The Women's Community Center will be a model for safer building practices, and act as a nexus for community building by supporting healthcare, education and microfinance initiatives. It will also aid in the establishment of support networks and social mechanisms to act as an ad-hoc disaster recovery center to assist recovery efforts in the likely event of future natural disasters.

Keywords: Nepal, sustainable, affordable, safe, community

1. Introduction

In April and May of 2015, two 7.8 and 7.3 magnitude earthquakes destroyed an estimated 700,000 homes and leftover 2 million homeless in Nepal. Women and children have been left particularly vulnerable by the quakes. Human trafficking of women and children, a long-standing problem in Nepal [1], has been exacerbated in the months since the quakes. [2][3][4]

In the Sindhupalchok region some 80% of structures were either destroyed or damaged beyond repair [5] including the physical conduits through which a variety of small-scale development programs including micro-finance and micro-health were delivered.

Such was the case in Bahunipati, a village of approximately 5500 people, where pilot micro programs were delivered through the Bahunipati Health Center (BHC), which was damaged beyond repair by the quakes. However, since its destruction, BHC's healthcare programs are being implemented on an ad hoc basis and the pilot micro programs (which are secondary to the BHC mission of providing community healthcare and medical staff training) have been put on hiatus.

2. Seismic History and Building Codes

Due to its location straddling the interface of the Indo-Australian and Asian tectonic plates, seismic activity in Nepal is expected. These recent quakes are part of a seismic history going back to at least 1255, with major earthquakes occurring in 1263, 1408, 1681, 1810, 1833, 1866, 1934, 1980, and 1988 causing varying degrees of widespread damage and loss of life. [6] Yet, despite this history, Nepal did not have an official building code until 1994 when the first code was issued in response to the devastation caused by 1988's tremor. [7] Even now, that code is relatively incomplete by developed nation standards with much of it taking the form of recommendations. It contains only rudimentary seismic considerations, applies primarily to urban areas, and it has not been fully adopted nationwide. In fact, only in response to the 2015 quakes has any sort of rural construction approval process been developed. As of August 14, 2015, the Ministry of Federal Affairs and Local Development issued a Basic Guideline on Settlement Development, Urban Planning and Building Construction that requires that Village Development Councils (VDCs) approve new houses. [8] The Basic Guideline required that VDCs meet, endorse building codes and set up an building approval process. Early reports, however, indicate that the initial deadlines were missed, in part due to lack of approved designs. [9]

3. Changing the Rural Construction Paradigm

In rural Nepal, construction tends to be done rather haphazardly, on an as needed basis, often without design documents, and using materials available at hand. [10] Post disaster re-construction often follows a familiar pattern: damaged and destroyed structures are simply repaired or rebuilt with available materials, and generally in a form identical or similar to that which the disaster had just demonstrated was unsafe. This is hardly surprising. Much of the country is rural, extremely poor and does not have the dedicated construction industries that are common in more developed countries. Most, if not all, rural construction is neither permitted nor regulated. Building inspectors and code enforcers don't exist in most rural areas. Design documents, procedures and standards that more developed nations take for granted are also uncommon outside of urban areas (and sometimes not even used there despite legal requirements).

The goal of the project discussed in this paper is, on a small scale, to change this rural reconstruction paradigm by "enhancing disaster preparedness for effective response and to 'Build

Back Better' in recovery, rehabilitation and reconstruction." This goal is in line with the Sendai Framework adopted at the recent Third UN World Conference on Disaster Risk Reduction, held in March 2015 in Sendai, Japan in which Nepal participated. [11]

4. Himali Dream Partnership

In the immediate aftermath of the 2015 quakes UNM4Nepal was formed by a group of students and faculty from the University of New Mexico's engineering, architecture, and economics departments, many of whom had existing ties to Nepal through family connections or ongoing academic projects and collaborations. This group quickly made contact with UNM's Nepal Study Center (NSC), and through the NSC, four Nepali organizations: the Pratiman-Neema Memorial Foundation (PNMF), the Lumbini Center for Sustainability (LCS), Kathmandu University (KU), and a private Nepali engineering firm: Construction Management Technologies Pvt.), Ltd. (CMT). Together these groups developed the Himali Dream Partnership (HDP) to address the needs of the poorest Nepalis.

The initial goal of the HDP was to focusing on the development of safer single-family homes. UNM4Nepal began making plans to develop an affordable, sustainable, and safe design, raise funds, travel to Nepal, and construct a prototype within a six-month window. Logistical realities, however, made this timeline untenable. Further, it quickly became apparent that there were many groups on the ground shortly after the earthquakes addressing immediate housing needs. International and homegrown long-term housing options were also being developed. For example, a prototype sustainable home was designed in Nepal by Prof. Dr. Deepak Bhattarai (one of the authors), to provide inexpensive and long-term shelter for a family of four to five. Circumstances thus led the HDP to reconsider its goals.

5. Project Development

Providing a conduit for reestablishing micro development programs was crucial to the project; but HDP did not simply want to provide an office from which to redistribute micro-loans and searched for a way to make a larger, more lasting impact. PNMF determined that the village of Bahunipati needs a central location to regroup, feel safe, and communicate with one another as the village rebuilds after the earthquake. This place should facilitate education, shelter, and provide a place to cook. This place should be both structurally sound and make the people feel safe from a psychological sense. It should also be able to play a role in central emergency management in the case of future natural disasters.

To evaluate various project options, HDP framed the issue of sustainability in terms "of what, to what, and for whom?" HDP focused on the intersection of economic development and engineering, answering the questions thusly: analyzing the ability of sustainable, resilient, multi-use infrastructure, to withstand foreseen and unforeseen natural disasters, for poor rural Nepali villagers, specifically by empowering the women of those communities.

While maintain its focus on sustainable structures, the HDP developed five basic criteria to move the project forward. Any structure developed should:

- be resilient and able to withstand expected natural disasters,
- benefit a large group of people,

- support the micro programs which had been disrupted by the quakes,
- act as conduit for transmitting safer building practices, and
- play a role in central emergency management.

HDP determined that developing and funding the construction of a sustainable and resilient Women's Community Center (WCC) would meet its objectives.

6. Resiliency and capacity

The WCC is meant to be a cornerstone village structure which will survive foreseeable disasters. It must have a minimum capacity of 40 people and incorporate three basic elements: indoor and outdoor community meeting space, a community kitchen, and sanitary facilities. The building must be resistant to high winds, reasonably resistant to seismic activity (built in such a way that unforeseen collapse will not lead to loss of life), and located out of known landslide and avalanche paths.

Structural designs being evaluated fall into three basic categories:

- engineered solutions which can be manufactured in Nepal, based on the manufactured steel truss modular home design developed by co-author Prof. Dr. Bhattarai, [12]
- shipping container based structures, similar to those created by Japanese architect Shigeru Ban and others [13], and
- structures constructed wholly from traditional materials.

Additional functionality will be incorporated into the design as it is defined and refined by the UNM undergraduate students who are investigating value added components for the prototype building, such as water catchment systems, solar cells to provide power for lighting and small electronics, improved cooking stoves, clean drinking water, and latrines.

Design and testing will be finalized by December 2015 to provide enough lead time to make final land procurement arrangements and assemble required materials and equipment on site. In Summer 2016, a group of UNM4Nepal members will travel to the Nepali village of Bahunipati to assist in the construction of the first community center.

7. Micro-program Support

The WCC will benefit the women of Bahunipati and their families immediately by providing a location to re-implement, revitalize and expand quake impacted micro development programs. These micro programs play an important role in rural communities, reducing poverty [14][15], and increasing women's social capital [16], particularly when other services related to health, education, training and technological support are included. [17] Research conducted in Bahunipati by the NSC demonstrated conclusively that pilot micro-finance programs specifically targeting 135 women in Bahunipati provided statistically significant economic and health benefits for them and their families. [18] Further, a recent study of determinants of microenterprise performance in Nepal, which included the Sindhupalchok region, found that microenterprises owned by women have relatively higher growth rates than those owned by their male counterparts. [19] Thus focusing on the women of the village makes sense. The WCC will also act as a nexus for future PNMF, KU and village-developed community-building projects, which will positively impact the village as a whole.

8. Safe Building Repository

The WCC will specifically address Sendai Framework Priority 4 by acting as an open access repository for safer, open source, housing designs and information on building techniques for villagers in Bahunipati and surrounding communities. It will itself be a model of safer construction and provide a central location from which to disseminate information about safer building practices. It will also provide an avenue for VDCs to integrate (and in some cases introduce) safer building practices in rural areas so that future seismic activity is not so devastating in terms of loss of life and property.

Finally, the WCC will be a conduit for continued community engagement and future HDP/Bahunipati collaborations relating to infrastructure improvement, the dissemination of safe housing designs, building methods, water, and sanitation programs.

One such housing design, developed by CMT and currently being analyzed and tested at UNM to ensure its ability to survive expected disasters, will be made available. Additional designs are reported to have been approved by the Nepali Government and as they are made available, they will be added to the repository. Placing these resources in the hands of the WCC will enable women to be educated about safer building practices, making it less likely that they will be marginalized in future routine and post disaster relief rebuilding efforts.

9. Emergency Management & Disaster Recovery

As is the case everywhere, natural disasters in Nepal are inevitable. While the impetus for this project was reaction to the recent earthquakes, in Nepal flooding, landslides and epidemics are a greater threat in terms of ongoing damage and loss of life. [20] It is important that there be robust structures in place that can withstand such natural disasters so that people have a location to congregate and disseminate aid and information.

Western agencies such as the United States Federal Emergency Management Agency (FEMA) use disaster recovery centers (i.e. “a readily accessible facility or mobile office where applicants may go for information about FEMA or other disaster assistance programs” [21]) for a variety of services including disaster recovery guidance, housing assistance, crisis counseling, and legal services. Such facilities generally do not exist in rural Nepal.

One goal for the WCC is that it will be able to act as an ad hoc disaster recovery center (similar to the high school gymnasium in the United States). For this reason, kitchen facilities, sanitary facilities, small scale power generation, and water treatment components are being incorporated into the design.

Further, in any such disaster, the ability of a village to recover depends on access to information and resources. Many Nepali villagers affected by the quakes have been vocal about the lack of both. For example, after the 2015 quakes, the Nepali government indicated that grants and loan programs would be available for reconstruction; but the implementation process proved difficult and confusion abounded among survivors of the quakes regarding the timing, terms, conditions, and availability of these proposed reconstruction funds. [22] While developing a comprehensive emergency response regime is obviously beyond the scope of the HDP, it does hope to facilitate dialog between Bahunipati villagers, the local VDC and the Sindhupalchok District Government to determine whether the WCC can act or as a more formal center by the national and VDC branches of the Nepali Government along the lines of a FEMA office.

10. Methodology

Design projects of this sort have been successfully accomplished before; such as the Cero Azul Community Center in Mexico designed by professors and students from California State Polytechnic University of Pomona. [23] To make this program different, the HDP will test the efficacy of an international academic/governmental/local partnership developing and constructing a facility in an impoverished nation which is attempting to make a radical change to its construction paradigm. Further, the collaboration discussed in this paper is somewhat unique in its approach both in terms of interdisciplinary interactions and the academic level of the student participants.

The underlying structure for these US-based HDP activities is an academic collaboration between UNM's Civil Engineering and Economics departments with input from the Architecture Department. Dr. Mark Stone and Dr. Mark Russell, along with other UNM Civil Engineering faculty members, used the HPD as an opportunity to create a Special Topics Class in the Civil Engineering department. This class, "Developing Sustainable Communities," is being taught by professors with construction, structural, hydraulic engineering, and economics expertise and includes both graduate and undergraduate students working in teams to achieve its goals. In conjunction, the introductory Civil Engineering class (CE 160, taken by students hoping to gain admittance to the Civil Engineering Department) has been revised to center around the HDP project, with graduate students from the aforementioned Developing Sustainable Communities class acting as mentors and guides to budding engineers. The goal of the classes is to develop a safe, inexpensive, adaptable community center design, which meets the aforementioned criteria.

The CE 160 class is normally devoted to developing CAD skills with some theoretical instruction about the design process. This year, however, the design process element of CE 160 has been brought to the fore and into the realm of reality using the HDP. The CE 160 participants usually have little to no prior design experience and their participation in the HDP provides a real-world focus for their academic endeavors that they would likely otherwise not receive until much later in their undergraduate academic careers. Furthermore, the undergraduate's early entry into such a long-term service project provides the opportunity to see their contributions come to fruition and for continued involvement in the HDP. The fact that one or more undergraduates may be part of the travel team has been a particular stimulant for their participation.

Undergraduates are learning the basics of the design process, assisting with determining design criteria and constraints, and are researching various solar, clean water, and sanitation technologies, which are being presented, and evaluated by their peers, mentors, and professors. The best of these technologies will be engineered into the final WCC design.

At the graduate level, UNM participants are coordinating closely with PNMF, KU, and LCS to develop the prototype WCC, and will

a. provide digital modeling, seismic and wind testing of the final design;
b. conform that design to international building codes; and
c. create a set of open source, easy to read construction documents which will be made available free of charge.

Undergraduates are participating in these elements of the project as well, though in more of an apprentice role.

11. Conclusion

The WCC should thus help enhance the economic prosperity and resilience of Bahunipati village in terms of both its prosperity and ability to survive and bounce back from disasters, natural and otherwise. If the pilot project is successful, HDP will replicate the WCC model and process in other areas thereby providing location, capacity, and resources for shattered Nepali communities to rebuild themselves.

Social connections created through the use of the WCC may provide the underpinnings of future disaster relief networks. Creating a community center that will survive most anticipated disasters and play a role in future disaster recovery efforts can provide a hub for the local citizens and a model for other communities. By establishing a repository for approved building plans and teaching materials, the WCC will ensure safer construction methods to incrementally create a safer village infrastructure, and provide an avenue for financial, healthcare, and other support.

The HDP is meant to be long-term partnership and includes fundraising from private and corporate donors to cover design, educational and construction costs. It is hoped that insights gained from the Bahunipati pilot will make future construction in rural Nepal more resilient.

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Resource saving potentials through increase recycling in the building sector – sensitivity studies on current and future construction activity

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Summary

Despite adequate supplies of materials for recycling as well as the introduction of dedicated norms on the use of recycled materials, a poor level of secondary raw material use persists in the building industry. Before political action can be taken to improve this situation, it is first necessary to gain a clear picture of current and future material flows, and in particular, which rates of recycling can be achieved when good framework conditions for the circular flow of materials are implemented. The aim of the described research was therefore to determine the potentials for the high value recycling of construction and demolition waste from buildings by means of sensitivity studies. Estimates were made of material flow masses in the building sector for 2010 as well as projections for the years 2030 and 2050.

Keywords: resource efficiency, recycling potentials, development of building stock, material flows, urban mining

1. Introduction

In the year 2002 the German government adopted a national sustainability strategy [1, 2]. Since this time concrete guidelines and indicators have shaped the path towards sustainable development. These are closely linked to the aim of conserving natural resources through improved efficiency. Specifically, the government decided that resource efficiency should increase by 50 % to the year 2020 (from the base level in 1990).

A nation's overall resource efficiency is determined by the gross domestic product (here in euros) and the total flow of materials (in tons). Hence the building sector, which consumes huge amounts of primary materials (such as sand, gravel, crushed stone, concrete, etc.), clearly has a major impact on resource efficiency. Lower demand for primary materials, e.g. through new construction techniques or the use of recycled materials, will therefore directly impact resource efficiency at the national level. Despite the importance of recycling, recycled materials still make up a small proportion of total material mass. Although in most cases recycled materials are available in sufficient quantities, and their use in particular applications is already permitted by construction norms, there has been a low uptake of recycled materials in the building sector. Political action is required to remedy this situation. Yet before politicians can get to work, it is necessary to describe as precisely as possible the current and likely future state of the building sector. This was the intention of the investigation described here.

Specifically, the research aim was to examine the potential for increased high-grade recycling of construction and demolition waste. Material flows were examined for 16 construction materials/products (see table 1). The first step was to gather data on construction activity (new buildings, renovation and demolition) for 2010[1], the beginning of the period under consideration. From this data it was possible to forecast material flows for the years 2030 and 2050 [3, 4]. Two research avenues were pursued simultaneously. On the one hand, we investigated the origin, composition, collection, sorting and recycling paths of the 16 building materials/products. This involved the setting of “optimistic” recycling ratios in discussion with experts on the building sector as well as representatives of trade federations. On the other hand, a material flow model was developed in order to provide a quantitative picture of current and future construction activity.

The objects of investigation were the potentials for the circular flow of material within Germany’s stocks of residential and non-residential buildings – from buildings to buildings. Thus the question of related infrastructural work (utility connections, access roads, etc.) is here ignored.

2. Methodology

The calculations to derive recycling potentials took the form of four sensitivity studies. These studies determined the extent to which recycling ratios can be increased through different forms of construction as well as new recycling technologies and application conditions. These factors were investigated within a specially developed material flow model, for which input data was required to describe the intensity of activities in the building sector (Fig. 1).

Two different analytical paths were linked in the material flow model: Data on the size of the building stock and the intensity of building activities was captured in a top-down view, while the material constitution was determined in a bottom-up view. The quantitative top-down path made use of all available statistics on the building sector [5]. The bottom-up characterization took the form of a building material matrix, which could be used to translate official data on the stocks of residential and non-residential buildings into material flows and material masses.[2] These calculations made use of a typology of residential and non-residential buildings, employing material indicators for type of construction and for technical installations [6, 7, 8]. By considering the specific material indicator values for building types, the data on the stock of residential and non-residential buildings as well as on estimates of current and future construction activity (new buildings, renovation, demolition), it was possible to calculate the total mass of materials within buildings stocks as well as the total material flows. The results of the sensitivity studies were values in tons of material stocks as well as material input and output flows. Recycling potentials could then be derived by applying the estimated recycling ratios.

[1] 2010 was set as reference year because of availability of data.

[2] The bottom-up characterization calculated all material flows as determined by official statistics. This took account of the main core of construction activities. Statistically irrelevant structures (e.g. free-standing garages), external structures (e.g. supporting walls) and extraordinary buildings (e.g. airports) were not included in data.

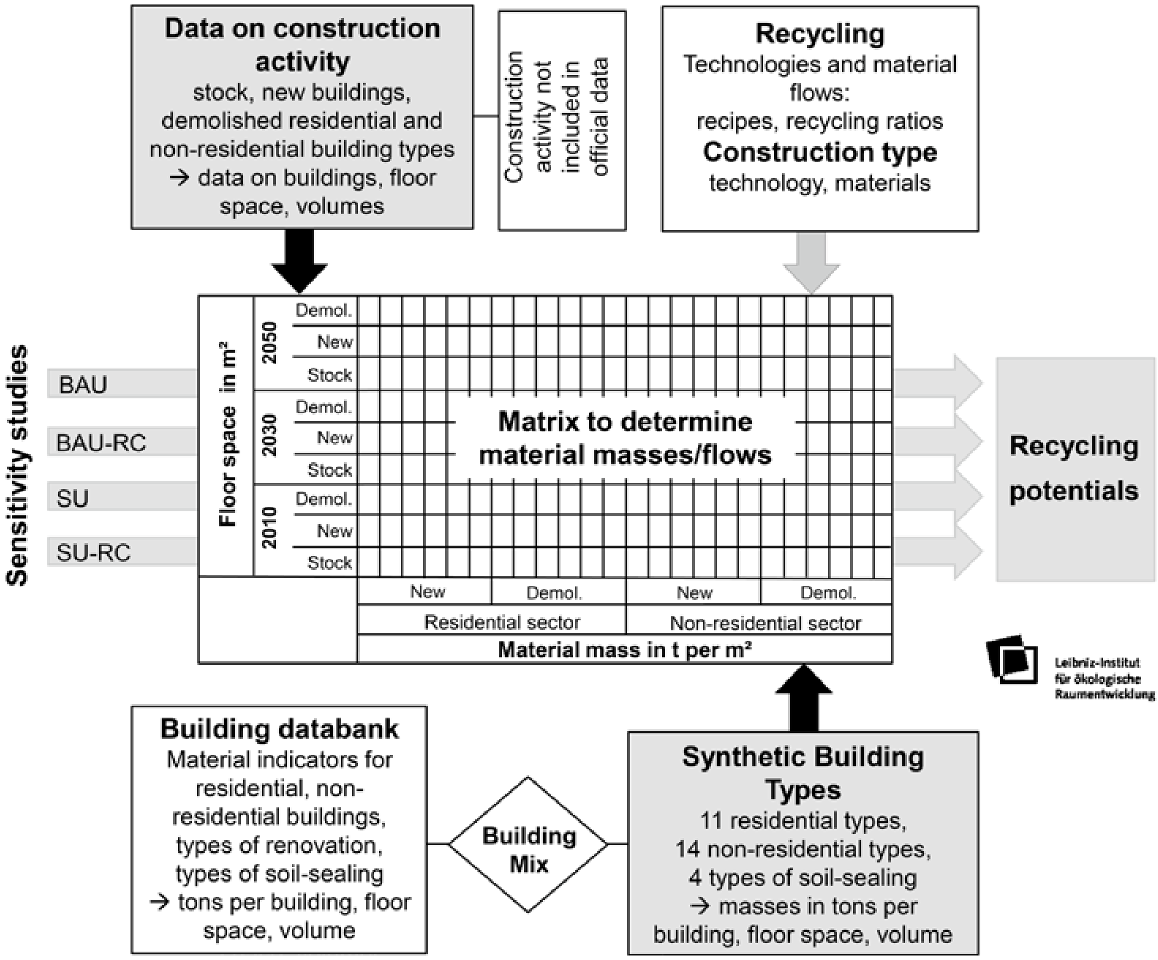

Fig. 1: Overview of material flow model [based on 3, p. 22]

2.1 Synthetic building types

11 such synthetic building types (based on period of construction) were formed to reflect the range of residential buildings. Here a distinction was made between one- and two-family homes as well as multi-family homes. 14 synthetic building types were specified for non-residential buildings. Here the types were distinguished by usage. The synthetic building types were created by abstracting a number of real buildings present in the IOER building databank (unpublished). In order to create a specific type, data on suitable existing buildings was captured and then averaged out to produce a standard (or synthetic) type.

2.2 Construction activity

Construction activity encompasses all activity that increases or decreases the building stock in the form of new buildings, conversions, extensions, renovations, partial or complete demolition and the joining of separate buildings into single structures. Data from national statistics [5] was used to calculate previous and current construction activity. Future construction activity was based on population forecasts for the year 2050. The factors and assumptions for the “translation” of demographic trend into building activities are presented in detail in the publications by Banse & Effenberger 2006 [9], Gruhler & Böhm 2011 [6] and Deilmann et al. 2015 [3].

Statistics were available on the stock of residential buildings [5]. These provided a framework for estimates of material masses of this stock. To overcome the problem of a lack of official statistics or sufficiently verified data on the stock of non-residential buildings, it was possible to turn to previous and current studies [10, 11, 12].

2.3 Recycling ratios

The possibilities of incorporating recycled materials into new building materials and products were discussed with experts in this field [3]. It was agreed that the estimates of likely recycling ratios should only be used within the described sensitivity studies and must not in any way be considered as target values for the setting of national sustainability goals. The recycling ratios specified for the sensitivity studies are indicated in table 1. In the material flow model these ratios were applied to the varying intensities of construction and the derived material flows.

Table 1: Ratios of recycled materials (RC ratios) determined for the sensitivity studies [3, p. 96]

	RC ratios (in %) for products in the building industry		
Material and product	2010	2030	2050
Concrete	0.4	6.0	12.0
Brick	0.0	10.0	15.0
Calcium silicate brick	0.0	5.0	5.0
Porous concrete	0.0	2.0	5.0
Other minerals /fill material	6.0	21.0	21.0
Plasterboard	0.0	30.0	50.0
Other plaster products	0.0	0.0	5.0
Timber	0.0	0.0	0.0
Plywood panels	4.0	10.0	20.0
Plate glass	15.0	25.0	35.0
Mineral-based heat insulating materials, approx 40 % rock wool RC ratios 0, 15, 20	27.0	42.0	56.0
Oil-based heat insulating materials	10.0	19.0	19.0
Plastic doors/windows	13.0	25.0	50.0
Other plastics /PVC flooring/carpets	1.0	5.0	10.0
Metals (only supplementary data, not part of investigation)	50.0	60.0	70.0
Other	0.0	2.0	5.0

2.4 Sensitivity studies

Material masses/flows for the years 2030 and 2050 were examined in four sensitivity studies, entitled BAU, SU, BAU-RC and SU-RC [3]. The same initial data on the building sector formed the basis for all studies. Table 2 describes the differences between the studies.

Table 2: Sensitivity studies – description [based on 3, p.93-94]

Sensitivity study	Description
BAU	Business As Usual: Current RC ratios remain unchanged up to 2050. Building stocks reflect the assumptions on construction activity for 2030/2050.
SU	Sustainability: Current RC ratios remained unchanged up to 2050. Construction activities changes as follows: Ratio of timber construction in residential housing rises from 15 % to 30 % for one- and two-family houses, and from 2 % to 15 % for multi-family houses. A 10 % reduction in material mass is achieved in concrete elements by new concrete mixes and forms of reinforcement. Triple glazing becomes standard in many non-residential buildings. The mass of insulating material increases by 30 % from the current level. Only half as many one- and two-family houses are built as indicated for “BAU”, yet this is compensated by more housing units in multi-family houses.
BAU-RC	The RC ratios viewed as optimistic by experts are achieved by 2050 for “BAU”.
SU-RC	The RC ratios viewed as optimistic by experts are achieved by 2050 for “SU”.

3 Results

3.1 Construction activity and material flows – Germany 2010

3.1.1 Construction activity

In 2010 Germany’s stock of residential housing was approx. 18 million buildings with a total floor space of approx. 3.6 billion m² [5]. In the same year around 84,000 new residential buildings were built, providing an extra 16.2 m² floor space, while around 6,313 residential buildings were demolished, reducing the total residential floor space by around 2.1 m² million. Taking account of the age of the various building types as indicated in official statistics, it is possible to assign the material masses from demolished buildings to the various building types.

No official statistics are available for Germany’s stock of non-residential buildings. Based on recent research findings, the usable floor space of the non-residential building stock is estimated at 3 billion m^2. This total area can be broken down according to the various types of non-residential building as recognized by official statistics. This distribution of floor space reflects the average ratios between the types of non-residential building by considering the floor space (in m²) of newly constructed buildings. Thus in 2010 a total of 26,990 non-residential buildings were erected, providing a total usable floor space of 25.5 million m² [13, 14]. In the same year around 9,000 non-residential buildings were demolished, reducing usable floor space by 6.5 million m².

3.1.2 Material flows

The total material mass in Germany’s building stock in 2010 can be estimated at 15.3 billion tons. Around 85 % of this was in the form of mineral-based materials such as concrete, brick, calcium silicate brick, porous concrete and other materials (screed, grout, sand, gravel, grit and crushed stone). Around 121 m tons of material flowed into the building stock in 2010 (input) while there was an outflow of around 42 m tons (output) (see table 3). These figures, which are largely determined by the general building activities (new construction and demolition), show that the stock takes on 7.9 ‰ (input) and losses 2.8 ‰ (output) related to the total material mass in the stock of buildings. In theory the output represents waste material for recycling.

3.2 Developments in the building sector and material flows – Germany in 2030 and 2050

3.2.1 Future building activity

Future developments in the housing sector are closely linked to the number of households and the demand for housing. In contrast, the development of the non-residential building stock is largely determined by demographic trends. For the current study, assumptions on population and the number of households were derived from 10 to 12 coordinated population forecasts [15].

In regard to the housing sector, we estimated that 7 million new housing units would be built by 2050. Over the same period, it was assumed that approx. 7.3 million units would disappear from the stock by 2050 [16]. Using these figures and taking account of the expected fall in the population, it can be estimated that *per capita* floor space in Germany will increase by around 11 % from 2010 to 2050.

The non-residential sector we draw on the hypothesis that demographic trends influence the stock of non-residential buildings [16]. Population-based parameters were devised by considering data from previous years (*per capita* usable floor space for new and demolished buildings in m²). These parameters, together with forecasts on population for 2030 and 2050, can be used to calculate values for useable floor space for new and demolished buildings for these two years. The estimated trend is for *per capita* usable floor space to rise by a maximum of 30 % from 2010 to 2050.

3.2.2 Material flows and recycling potentials

The input material flow for new buildings, extensions and renovation work will scarcely change in the period up to 2030: the figure is approx. 121 m tons for 2010 and 2030. In contrast, the material output flow due to deconstruction work – in particular partial or complete demolition – will increase from 42 m tons in 2010 to 64 m tons in 2030, a jump of 52 %. A clear break in this trend is expected by the year 2040 at the latest due to the continually falling population. The material mass for new construction in the year 2050 is expected to be 55 m tons lower than in 2010, i.e. a drop of 45 %. At the same time the mass of material issuing from deconstruction work will increase by 62 m tons, i.e. a jump of 150 %. Compared to the figure for 2010, the total mass of material flows (input and output) will be 13 % higher in 2030 and 4 % higher in 2050 (Tab. 3, BAU and /BAU-RC).

Estimates for the mass of recycled materials used for new construction and renovation work is based on the described material flows. The estimate of approx. 8 m tons recycled materials for 2010 (based on the current RC ratio) is only approx. 7 % of the corresponding figure of 121 m tons of primary material. If the framework conditions for the recycling of waste materials improve (cf. assumptions in Tab. 1) then the use of recycled materials could peak in 2030 at a mass of 19 to 20 m tons. Thereafter the mass will decrease to a level of about 12 to 14 m tons by the year 2050 (Tab. 3).

Table 3: Input and output material flows as well as recycling ratios in m tons for the years 2010, 2030 und 2050 – comparison of sensitivity studies [based on 3, p. 100 and 101]

	Material flows and recycling ratios in m tons								
	2010			2030			2050		
Sensitivity study	Input	Output	RC in input	Input	Output	RC in input	Input	Output	RC in input
BAU	121	42	8	120	64	8	66	104	5
BAU-RC	121	42	8	120	64	20	66	104	14
SU	121	42	8	113	64	8	60	104	4
SU-RC	121	42	8	113	64	19	60	104	12

The drop in the absolute mass of recycled materials can be attributed to a falling rate of new constructions, reflecting demographic trends. A contracting population means lower demand for new buildings both in the residential and non-residential sector. This serves to lower material flows for new construction and thus the absolute mass of recycled materials. Hence the mass of recycled materials will drop by some 30 to 35 % in the period 2030 to 2050 even though the proportion of recycled materials (based on the investigated 16 material types or products) will increase from approx. 16 % in 2030 to approx. 21 % in 2050 (Fig. 2).

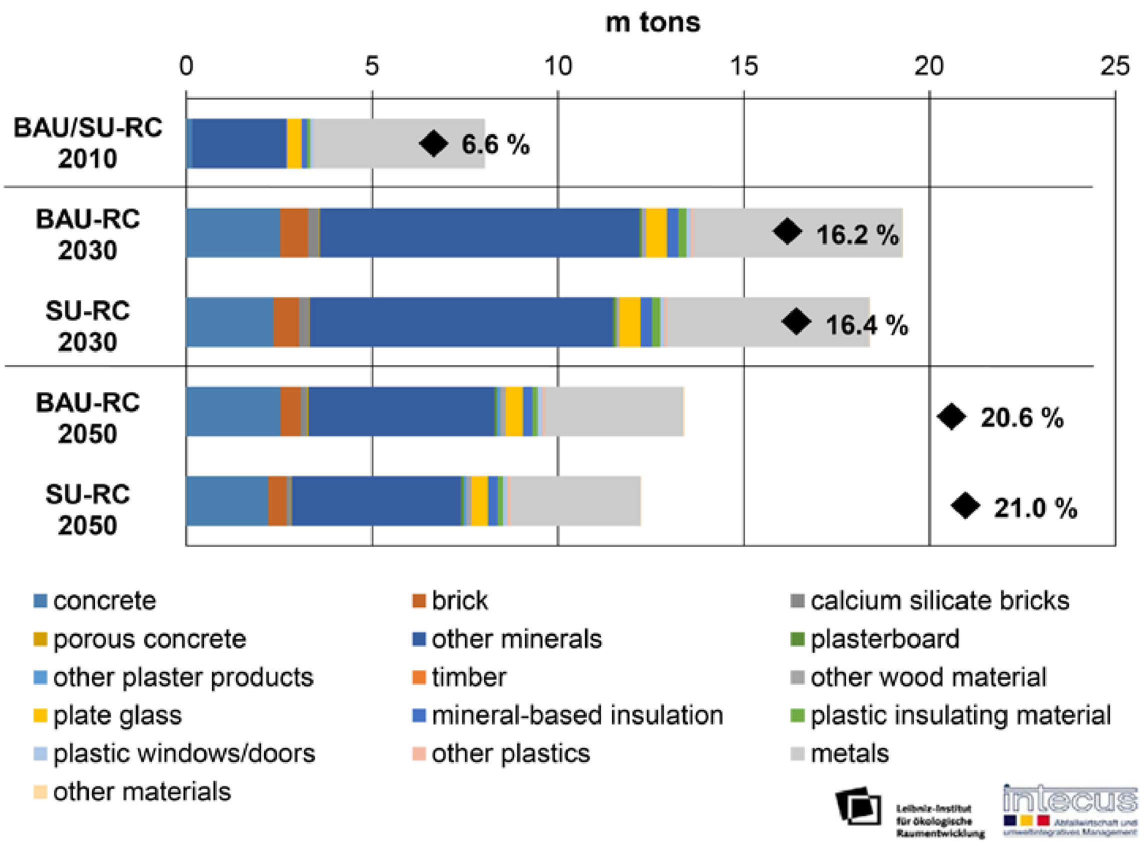

Fig. 2: Mass of recycled materials in m tons and average recycling ratios – comparison of sensitivity studies [3, p. 98]

Alongside metals and concrete, the third major type of recycled material is other mineral-based materials. Here the greatest potential to increase recycling ratios is to use such materials as fill. These can be sand, gravel and crushed stone for the blinding layer and foundation slabs, to construct access roads, car parks and patios on private land, as well as bedding for the laying of utility pipelines and to fill other infrastructural trenches. The simplest and most effective way to increase the proportion of recycled mineral waste material is therefore to use this consistently as fill material for damp-proof courses, levelling sand and pipeline trenches as part of buildings.

4. Discussion

In the described research we have undertaken sensitivity studies to illustrate and describe developments in Germany's building stock and its impact on resource consumption (material flows for the years 2010, 2030 and 2050). It is estimated that the total mass of material flowing into and out of the building sector will rise from 163 m tons in 2010 to 183 m tons in 2030 before falling back to 170 m tons by 2050. But the ratio between input and output flows will also change during these periods: In 2010 input was almost three times output; in 2030 it will be only twice as large; by 2050 input will in fact be lower than output. One likely scenario is that the use of recycled materials will peak in 2030 at between 18 and 20 m tons, falling by 2050 (despite a higher recycling ratio) to around 12 to 14 m tons due to a contracting building sector. At the same time the average recycling ratios can be expected to rise from only 7 % in 2010 to 16 % in 2030 and 21 % in 2050.

Despite sufficient availability of recycled materials for a range of applications (as determined by norms on building material), contractors, project developers and manufacturers of building materials have so far been reluctant to fully exploit mineral-based recycling materials, for example in concrete or brick structures. Thus although construction norms and standards permits a wide variety of materials to be used as aggregate, almost the only form of processed building waste currently employed in Germany as aggregate for concrete structures is high-grade concrete rubble. Furthermore, this recycled material makes up only a small fraction of total aggregate. Hence the potential of using recycled rubble as aggregate remains only partially realized.

Actors in the building sector frequently underestimate the relevance of (private) infrastructural work such as the construction of access roads, patios, supporting walls and household connections to public utility networks, for the recycling of materials. Yet the simplest way to increase the proportion of recycled materials in the building sector would be to consistently replace the fill materials required by builders for damp-proof courses, for levelling sand under floor panels, for infrastructural trenches, for parking spaces and garages as well as for pipeline bedding by recycled materials.

5. Conclusion

One important goal in the field of environmental policy is to conserve our natural resources. Material recycling in the building sector can play an important role in achieving this goal by substituting large volumes of primary raw materials with recycled materials.

Unfortunately, the revealed potentials are still not fully exploited in practice. There are multi-layered, complex reasons for this deficit: A lack of practical solutions to increase the circular flow of materials, strict regulations on the range of substitute materials, high quality standards applying to recycled materials, etc. In general, it is vital to promote the recycling of materials within the building sector and to undermine resistance to recycled materials and products. At the same time more high quality data needs to be gathered on building waste. Material recycling can be boosted if the building sector and related infrastructural activities are always seen as forming a single complex system of material flows. Recycled materials should always be preferred when relevant standards permit their use, regardless of whether these materials originate from the building sector or from infrastructural activities.

If more recycled materials are to be used in both the building sector and in related infrastructural work, then a competitive market will arise for these products. The availability of recycled materials depends both on the volume of building waste and the distances between demolition sites and sites undergoing development. Regional cost-benefit models must therefore be drawn up for mineral materials in order to take account of the transport distances between dynamic regions and those undergoing contraction. However, transport distances and related costs are largely irrelevant in the case of metals and other high value recycled materials, so that the use of such materials does not require cost-benefit analysis.

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Risk and scenario-based approach assessing sustainability

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Summary

Future developments such as global climate change, shortage of resources or ageing society are so-called megatrends which can significantly affect the future viability of a property. Depending on the attributes of property, these developments may introduce either a risk or an opportunity due changing requirements for property. To this end, previous study identified a set of 34 sustainability indicators which in turn constitute the sustainability rating, namely the Economic Sustainability Indicator (ESI Germany). In the current study, further assessment was conducted as the ultimate aim is set to weight the previously identified indicators by adopting a risk and scenario-based weighting model. Therefore, the probability of occurrence of property´s future requirements and the impact of their consequences on property value are estimated and included in the risk model. Consequently, the sustainability rating assesses the risks and opportunities of German office buildings concerning the property´s future viability due to sustainability-related building and location attributes. The proposed rating model can be used in decision-making processes of investment decisions and portfolio management as well as for the consideration of sustainability aspects in property valuation.

Keywords: sustainability, rating, property evaluation, risk model, economic sustainability indicator

1. Introduction

In the context of sustainable development and the quest for sustainable environment, properties play a significant role, since effects of global climate change, shortage of resources or ageing society as examples for long-term developments of external framework conditions can significantly affect the built environment. These developments offer great potential for consumption and emission reductions using appropriate measures in real estate as the construction, occupation and recycling of properties are responsible for a high percentage of the global energy consumption and greenhouse gas emissions [1, 2]. In addition to the efforts of the policy, the efforts in the private sector are clearly identifiable, which can be quantified by the increased interest of investors and users in sustainable properties. Empirical studies revealed that the operating costs of sustainable, certified properties are lower than the ones of conventional properties [3]. Furthermore, sustainable properties feature an increased comfort and an improved labor productivity. And additionally, sustainability has positive effects on the image of the property or the owner [4]. Besides, sustainable properties can achieve price premiums on rental and sales prices as well as higher occupancy rates and lower vacancy rates in certain markets, even though the results of these empirical studies vary [e.g. 5, 6, 7]. Even though it can be assumed that the acceptance and willingness to pay for sustainability in German real estate is basically available, the proportion of those is relatively low. Beyond, sustainability is mainly relevant for new buildings or so-called milestone projects, whereas the proportion of existing sustainable and certified properties in Germany is around 30% and still limited [8, 9]. In order to enhance the attractiveness of investments in sustainable properties, it is essential to raise the awareness regarding the effect of sustainability issues on the performance of a property. Namely, the influence on property value and the associated opportunities and risks of a property resulting from changing requirements due to future developments. Although these developments may significantly affect the future viability of a property, they are often not or only insufficiently taken into account in decision-making processes of investment decisions and portfolio management or in property valuation [10]. In this context, this paper represents an approach for a sustainability rating evaluating the sustainability of German office properties with respect to the performance of risk and resulting from this, the future viability of a property: The Economic Sustainability Indicator Germany.

2. Background and Methodology

2.1 Indicators of ESI Germany

In the previous study [11], a set of sustainability indicators have been identified, which form the basis for the current investigation. These are derived from selected exogenous framework conditions, so-called megatrends, which can result in changing future requirements for property attributes and effect on property value. This set of 34 sub-indicators have been grouped in indicators and further in sustainability attributes. In total, there are five groups of sustainability attributes (Table 1): Flexibility and adaptability for third party use, energy and water dependency, accessibility and mobility, security as well as health and comfort [12].

Table 1: Overview of ESI-indicators

Sustainability attributes	Indicators	Sub-indicators	Characteristics
Flexibility and adaptability for third party use Flexibility of use/ adaptability to users **Energy and water dependency** Energy demand and production/ water use and sewage disposal **Accessibility and mobility** Public transport/ pedestrians/ non-motorized vehicles **Safety and security** Location regarding natural hazards/ building safety and security **Health and comfort** Indoor air quality/ noise/ daylight/ contaminations	23 Indicators	34 Sub-indicators	3 Characteristics in each case

The 34 indicators have been rated in three characteristics in each case and coded with the values +1, 0 and -1. Following assignments have been applied:

- +1 = “favourable” characteristic: The building fulfils the criteria of the sub-indicator (exceeds common standards and norms)
- 0 = mean characteristic: The building fulfils common building standards and norms
- -1 = “unfavourable” characteristic: The building does not fulfil the criteria of the sub-indicator (below common standards and norms).

The ESI-indicators have been verified by an expert panel from practice and research containing valuers, cost planners, property investors as well as real estate and construction academics. Moreover, these ESI-indicators have been tested on pilot projects.

2.2 Methodology

ESI Germany focuses on the risk of an office property depreciating value or the opportunity of gaining value due to long-term developments of external framework conditions. In order to assess the future viability of an office property, a risk- and scenario-based weighting model is being adopted. Therefore, long-term developments of external framework conditions, which may affect the relative value of individual property attributes due to changing requirements on real estate, are represented by various scenarios. In conjunction with the probability of all scenarios occurring as well as their potential impact on property value, the weighting of the individual property attributes within the sustainability rating is derived. Originally, the risk model has been developed for the Swiss ESI-rating and has been modified within this work in collaboration with risk experts [13]. Below, the model requirements including the individual model components, the parameters to be estimated and their implementation in the model are described in more detail.

- Representation of insufficient regarded value aspects: For the sustainability rating, solely property characteristics of German office buildings are relevant, which are subject to long-term developments of external framework conditions and may affect the long-term property value, but which are not or only insufficiently taken into account until now. Thus, in the current work potential future developments of long-term property value due to a change in framework conditions are represented.

- Scenario-based consideration: In order to encounter uncertainty of long-term developments, the range of potential consequences and the resulting changed requirements respectively is modeled by the means of scenarios.

- Risk-based consideration: The effects of long-term developments on relative value of individual property characteristics are quantified by estimating the probability of future developments occurring and the magnitude of their potential consequences on property value.

The model requirements described above are implemented by three model components: The scenarios of future developments S, their probability of occurrence $\rho(x_i)$ and the magnitude of consequences x_i for each sub-indicator K. As input parameters for the risk model, risk estimations of the probability of occurrence and the magnitude of consequences for each scenario are used. Below, they are described briefly [14]:

2.2.1 Scenarios

For modelling the scenarios, following basic assumption is applied: Long-term developments of exogenous framework conditions result in changed requirements for office properties. For example: As a result of global warming, the increase in prices of electricity and fossil fuels as well as the strengthening of legislation concerning the energy performance of buildings, reduced greenhouse gas emissions and reduced energy and water consumption are becoming increasingly important. It can be deduced that prices for fossil fuels will increase in the future. As a result, properties must meet higher standards in terms of energy quality in the future. Sustainable properties that can handle these developments due to “favourable” building characteristics will maintain or increase their value in the future respectively. In contrast, properties featuring "unfavourable" building characteristics will meet this change only difficultly and will probably decrease in value. In order to reflect the uncertainty of future developments, the potential consequences are described by the means of four scenarios for each sub-indicator: A maximum scenario $S_{max.}$, a medium scenario $S_{med.}$, a minimum scenario $S_{min..}$, and a zero scenario S_0. The four scenarios represent the likely and realistic range of future changes in demand and the relating potential requirements for each sub-indicator due to changed future developments. When modelling the scenarios, it is assumed that one of the scenarios will occur at the end of the observation period of 30 years.

2.2.2 Probability of occurrence

When estimating the probability of occurrence for each scenario, it is specified how likely properties must meet the future requirements described in the scenarios in 30 years. The estimated probability of occurrence of the scenarios $S_{max.} = x_1$, $S_{med.} = x_2$, $S_{min.} = x_3$, $S_0 = x_4$ of each sub-indicator K is indicated with values between 0 and 1 and can be described by following function.

$$\rho(x_i) = P(K = x_i) \tag{1}$$

For that matter, the sum of all probabilities is 1 which can be expressed as

$$\sum_i P(K = x_i) = P(K = x_1) + P(K = x_2) + P(K = x_3) + P(K = x_4) = 1 \tag{2}$$

Besides, the mean T of the distribution of K is defined as

$$T_K = \{x_1, x_2, x_3, x_4\}\ ;\ \ P(K \in T_K) \tag{3}$$

Hence, the probability of occurrence for each sub-indicator K is distributed in four classes corresponding to the four scenarios.

2.2.3 Magnitude of consequences

In addition to the estimation of the probabilities, the estimations of the magnitude of consequences on property value x_i are included in the risk model as well. Assuming that the particular scenario will occur in 30 years and the property can not meet the future demand (the corresponding sub-indicator is featured "unfavourable" (value -1) respectively), the consequences for each sub-indicator are indicated as a proportion of the property value. Therefore, the changes are quantified by estimations of changes on property value ("risk estimations value") or on costs ("risk estimations costs"). In order to unify the estimations, a reference object is used as a basis.
The "risk estimations costs" are estimated and expressed as additional costs in €/m² gross floor area (GFA) according to DIN 277-1: 2005-02. These additional costs cover the subsequent implementation of new requirements as part of a regular modernization and are estimated at current costs (future cost changes e.g. due to technological progress remain unconsidered). For some indicators, it is not possible to implement changes in demand and future requirements by the means of modernizations. As an example location dependent indicators correlating with the change in market demand can be mentioned. Or if the benefit of the modernization would not be in relation to the effort, e.g. addition of another storey, the magnitude of consequences is not expressed as cost implications, but as a change in property value. In these "risk estimations value", the estimated magnitude of consequences is expressed as the change in net rental income or as a percentage reduction in yield of the total net rental income respectively.

2.2.4 ESI risk model

The usage of all risk estimations in the model will be based on the simplifying assumption that the estimations of the "unfavourable" building characteristics are symmetrical to the estimations of the "favourable" building characteristics, which makes estimations for "favourable" building characteristics unnecessary. Before using the entire estimations of magnitudes in the risk model, the transformation of the estimations in one unit is required. In this context, the "risk estimations costs" are transcoded into the percentage change of the net rental income by the means of the market value of the reference object. In this way, the modelled scenarios S with their estimated probability of occurrence $\rho(x_i)$ and estimated magnitude of consequences x_i for each sub-indicator K can be used as input parameters in the model.
In order to receive the most objective estimation results as possible, the risk estimations had been carried out by real estate experts independently and on the basis of a reference object. Following this, the subsequently obtained consensus values are used as the input parameters of the risk model enabling the calculation of the expected values on the level of the sub-indicators, which are used to derive relative weights of all ESI indicators. The multiplication of the probability of occurrence $P(K = x_i)$ of each scenario with the corresponding magnitude of consequences on property value x_i with "unfavorable" building characteristics as well as adding up those products result in the risk related to the remaining building lifetime. This is expressed as the expected value of the relative change in value of a sub-indicator $E(K)$:

$$E(K) = \sum_{x_i \in K} x_i P(K = x_i) \tag{4}$$

Finally, the comparison of the expected values for each sub-indicator result in the relative weights of the 34 sub-indicators. Thus, the overall impact of the sub-indicators K is determined summarily on the change in net rental income, which is shown in an example (Table 2). After completion of weighting all sub-indicators, test applications are carried out in order to validate the achieved results. Concluding, the results are tested on pilot projects as well as using sensitivity analysis.

Table 2: Example – calculation of the expected value of the indicator K_4

Scenario	$\boldsymbol{P(K = x_i)}$	$\boldsymbol{x_i}$	$\boldsymbol{x_i P(K = x_i)}$
(x_1)	0.23	0.0417	0.0096
(x_2)	0.18	0.0267	0.0048
(x_3)	0.17	0.0158	0.0027
(x_4)	0.42	0	0
$\boldsymbol{E(K)}$			**0.0171**

3. Results and Discussion

3.1 Relative weights of the ESI-indicators

The calculated relative weights of all sub-indicators are displayed in Table 3. The highest total weight is held by the sustainability attribute “energy and water dependency” with almost 33%. This attribute is dominated by the sub-indicator “8 energetic quality” (around 29%). The other (sub-)indicators of this sustainability attribute evaluating the proportion of renewable energy use as well as the water consumption and rain water disposal, are less significant.
The sustainability attribute “health and comfort" is almost as important as the sustainability attribute “energy and water dependency” as it holds a weight of approximately 31%. However, it should be noted that within the energy group only five sub-indicators are combined, whereas the sustainability attribute 'health and comfort" covers nine sub-indicators. The highest weight within this group is assigned to the sub-indicator "23 contamination: contaminated sites" with 6.1%.The lowest weights of this sustainability attribute exhibit the indicators for the evaluation of radon (2.2%) and the individual adjustability of workplace environment (0.9%).
With a total weight of 18.6%, the nine sub-indicators of the sustainability attribute “flexibility and adaptability for third party use”, whose indicators vary mainly between weights of 1.7% and 2.9%, has also a relatively large impact within this rating. Within this group, the flexibility of the floor plan and the floor height (each almost 2.9%) are of greater importance than expandability (1.8%), the flexibility of the building services and the accessibility within the property (each about 1.7%). In addition, there are indicators with the highest and lowest weights within this sustainability attribute. These are the indicators to assess the flexibility of the construction design (4.3%) and the existence of barrier-free toilets (0.4%).
The individual weights of the sustainability attribute "accessibility and mobility” for the evaluation of the accessibility of the city center and the recreation areas surrounded as well as the quality (availability and frequency) of public transport are distributed with the exception of the indicator “15 Bicycle parking area” (2.7%) between weights of 0.9% and 1.6% relatively evenly. All together, these seven sub-indicators result in a total weight of around 10%.
The lowest weight of about 7% within the sustainability rating has the sustainability attribute "safety and security" with its four sub-indicators. Here, the two indicators for the assessment of the building safety and security measures (fire protection and technical safety devices) with approximately 3% are more important than the indicators evaluating the location regarding natural hazards (0.7%) and the lighting within a building (0.4%).

From the distribution of the described relative weights within the sustainability rating ESI Germany can be deduced that German office properties have a lower risk decreasing in relative value, if the energetic quality of the building envelope and heating systems as well as the sound insulation requirements for noise emissions meet at least the current standards and norms (29.3% and 4.3%), contaminated sites verifiable to not exist and structural building characteristics simplify the property´s flexibility, adaptability and deconstruction (6.1% and 4.3% respectively). This can be attributed to the fact that the compliance of the relevant requirements of the property´s characteristics is associated with considerable financial (added) expenses and/ or it concerns location-based characteristics.

Table 3: Weights of the sustainability rating ESI Germany

		Indicators	**Sub-indicators**	**Relative weights**		
Flexibility and adaptability for third party use	1	Flexibility of construction design	Convertibility, adaptability and possibility for dismantling of construction design	4.31%	15.29%	**18.61%**
			Flexibility layout	2.86%		
	2	Expandability	Horizontal and vertical expandability	1.83%		
	3	Storey height		2.85%		
	4	Flexibility of building services	Accessibility of building services	1.72%		
			Reserve capacity of building services	1.72%		
	5	Accessibility of the property	Manageable differences in height	1.25%	3.32%	
	6	Accessibility within the property	Negotiable height differences outside	1.65%		
	7	Barrier-free toilets		0.42%		
Energy and water dependency	8	Energetic quality	Energetic quality of building skin and heating engineering	29.26%	32.21%	**32.82%**
	9	Energy sources	Proportion of renewable primary energy for heating	2.11%		
			Proportion of renewable primary energy for electricity	0.84%		
	10	Water consumption	Water-saving furnishing	0.22%	0.61%	
	11	Rain water disposal		0.39%		
Accessibility and mobility	12	Accessibility of public transport	Accessibility of local public transport	1.31%	10.21%	**12.21%**
			Accessibility of long-distance transport	1.02%		
	13	Frequency of public transport	Frequency of local public transport	1.40%		
			Frequency long-distance transport	1.62%		
	14	Accessibility city center and recreation area	Accessibility local/ regional city center	1.24%		
			Accessibility recreation area	0.91%		
	15	Bicycle parking area		2.71%		
Safety and security	16	Location regarding natural hazards	Risk of storm, flood, etc.	0.70%	7.07%	**7.07%**
	17	Building safety and security measures	Illumination/ exposure	0.42%		
			Fire protection	3.13%		
			Technical safety devices	2.82%		

Table 3: Weights of the sustainability rating ESI Germany (continued)

		Indicators	Sub-indicators	Relative weights		
Health and comfort	18	Indoor air quality	Controlled ventilation concept	3.69%	31.29%	**31.29%**
	19	Sound insulation	Noise immissions	4.33%		
	20	Indoor acoustic	Airborne sound, footfall sound, sound of building services, etc.	3.87%		
	21	Daylight		3.83%		
	22	Individual adjustability of workplace environment	Influence of users	0.91%		
	23	Contaminations	Contaminated sites	6.14%		
			Radon	2.17%		
			Electromagnetic filed	2.97%		
			Harmful building products	3.38%		

3.2 Sensitivity analysis

For the determination of the dispersion for each calculated relative weight at the level of sub-indicators, the volatility of the expected values is investigated by the means of a variance-based sensitivity analysis. For each expected value of the sub-indicators, the corresponding coefficient of variation is determined and compared with the expected value. Figure 1 shows the comparison of the value pairs for each sub-indicator K. The expected values are displayed on the x-axis, whereas the corresponding variation coefficients are plotted on the y-axis. The diagram illustrates the volatility of the expected values of each sub-indicator, which reflect the relative estimation precision of each scenario in the risk estimations. From the diagram can be interpreted that the intensity variation of the expected values is not correlated with the amount of expected values. This can be attributed to the fact that no normal distribution, but a frequency distribution per sub-indicator exists for the probability of occurrence of the four scenarios in four classes. For this reason, the estimation of the four scenarios with respect to the estimated amount closer together within one sub-indicator than the aggregated estimation of each sub-indicator compared to each other.

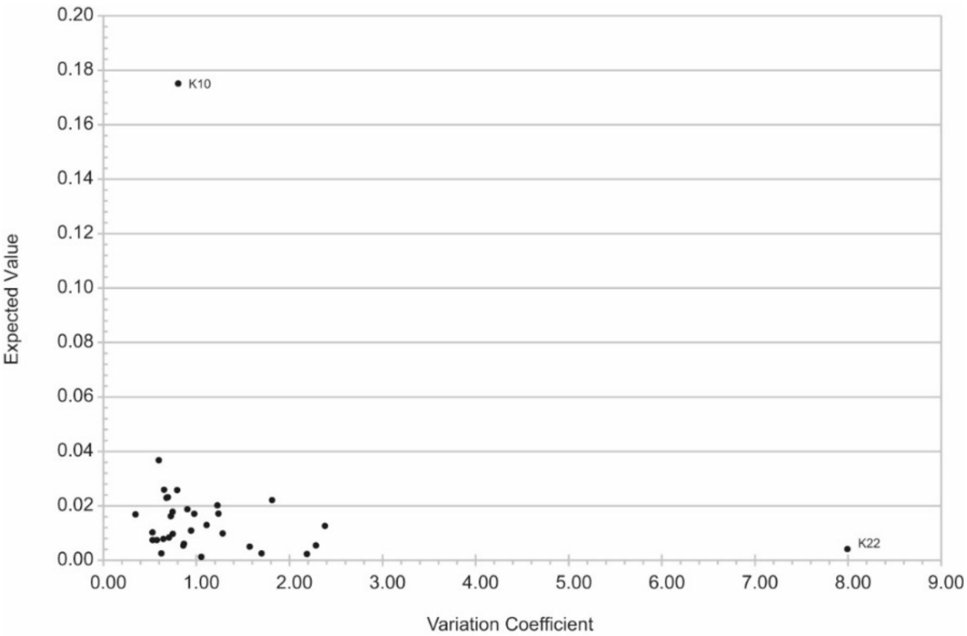

Figure 1: Dispersion of the ESI-indicators

4. Conclusion

The presented study introduces a risk and scenario-based approach for the assessment of value-related sustainability aspects of German office properties. ESI Germany attempts to quantify the consequences of long-term developments of external framework conditions such as global climate change or ageing society on the value of a property. Therefore, the previously identified sustainability indicators grouped in the sustainability attributes flexibility and adaptability for third party use, energy and water dependency, accessibility and mobility, security as well as health and comfort are weighted using a risk model based on scenarios and estimations of the scenario´s probability of occurrence and magnitude of consequences. However, the presented risk and scenario-based weighting model has its limitations. The estimated values used in the model remain with uncertainties and a certain level of subjectivity is unavoidable. Though, the estimations are made with best guess of experts and tested on pilot projects. Nevertheless, the presented study offer a possibility for the disclosure of the opportunities and risks regarding the property´s future viability due to sustainability-related building and location attributes transparently. Sustainability issues which are either not or only insufficiently taken into account can be thus regarded and integrated into the assessment. Uncertainties as a result of incomplete information particularly on future developments can be minimized. This results in well-founded and more transparent evaluations and can be used in decision-making processes towards sustainable development covering the ecological, economic and social level simultaneously.

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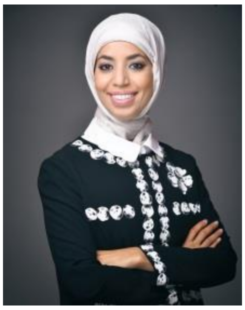
Risk Management for Construction Green Building in Kuwait



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Summary

This research aim to identify risks perceived for the implementation and practice of green construction in Kuwait to form a view of the likely impacts of these risks. Possible means of mitigating the effect of these risks are also presented in the effective implementation and continuous improvement of the process. After comprehensive reviewing the literature, the data is conducted and collected through quantitative approach by questionnaires survey. The judgmental and snowball sampling techniques are used for the data collection. The local stakeholders associated with the Kuwait construction industry were the target population and used as a platform to obtain the data. A total of 210 questionnaires were distributed and 132 completed questionnaires were received. In total, 30 perceived of risks organized in five groups have been identified and prioritized on the basis of criticality in the implementation of the green building process. A significant difference is observed in the perception of stakeholder's professionals from the level of their experience and sector of organization on the criticality of these factors. Further research could be done in other countries as well. This study will help the green building practitioners to develop plans to achieve their goals and improve the green building process on the basis of these outlined concepts

Keywords: risk, green construction, green building, built environment, risk management.

1. Introduction

The construction sector plays a vital role in meeting the needs of society and enhancing the quality of life. However, the responsibility for ensuring construction activities and products consistent with environmental policies needs to be defined and good environmental practices through reduction of wastes need to be promoted [1]. Indeed, Building and its construction activates have an enormous and continuously increasing negative impact on the environment, using nearly 40% of natural resources [1]., consuming about 70% of electricity and 12% of potable water [2], and producing among 45 and 65% of the waste disposed in landfills [3].

The poor quality of the indoor environment of the buildings may increase the risk of health problems faced by office-based employees, causing a decrease in productivity [4]. These negative impacts of the construction industry on the environment and the population are both serious and alarming. In order to overcome this situation and mitigate these effects, the new concept of "green buildings" has arisen. This concept has become the new philosophy of the construction industry and has introduced various enhancements to previous concepts i.e. use of more environmentally friendly materials and resources, improvement in quality of the indoor environment, and implementation of techniques to save resources and reduce waste consumption.

Green building (also known as green construction or sustainable building) is the practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance and demolition [5-6]. This process consequently encourages the creation of a healthier and more eco-friendly environment and is undertaken with the greatest possible level of cooperation and coordination of the design team, constructors, engineers and owners throughout the project in question. The "green building" construction process also provides the same standards of economy, comfort, stability and values of design and construction as classically constructed buildings. This leads to financial and economic advantages as well as increased social well-being.

Ultimately, a successful project is considered to be one that is delivered on time, within budget and that meets the appropriate standards. In order to promote the new concept of green construction, some factors have to be taken into consideration. Many countries have either already adopted green construction guidelines or are currently in the process of adopting them. As the benefits and advantages of green buildings have now been defined, it is important to identify the key drivers of these projects. It is also vital that the risks and barriers of implementing this concept are adequately investigated, especially in a country like Kuwait, where the 'Green' idea is a new model. In Kuwait, buildings consume about 40% of the country's primary energy resources [7]. These buildings also use a large amount of water, including water that is desalinated in power plants. This heavy usage of the country's limited natural resources and the damage done by products of extensive construction projects are triggering a shift towards making buildings more sustainable [8-9]. Substantial financial savings can be made as a result of the energy saved by sustainable construction; however, encouraging consumers to limit their energy usage is a difficult task in countries like Kuwait, due to the huge subsidisation of electricity by the government. In Kuwait, the government subsidises about 85% of the cost of electricity. In addition, consumers are charged a fixed amount of 2 Fils/kWh (0.006 $/kWh), whereas it costs 30 Fils/kWh to produce the energy [9]. This discrepancy is the principal driver in the increase in demand for electricity.

The green building movement offers many business opportunities to members of the construction industry. However, these opportunities carry significant risks and barriers. It is therefore necessary to understand and address the main drivers, barriers and risks associated with implementing new "Green" construction practices in order to manage them and accelerate the expansion of sustainable building projects. In order to assess the present state of the construction industry, this study focuses on a critical examination of the risks associated with implementation of the practice of green building projects from the stakeholders' perspectives

3. Methodology

In order to collate the primary data in response to the research questions, a questionnaire was used as a key tool for gauging the respondents' perception of various aspects of green building practices implemented in Kuwait. The literature review served as the basis and guidelines for designing the questionnaire. A pilot study was conducted in order to ensure that the instructions, language, scale items, and understanding of the questions used in the questionnaire were clear[10]. The questionnaire was delivered to a list of 10 stakeholders involved in the construction industry to observe difficulty and problems during the response process. The group was asked to comment on the readability, accuracy, and comprehensiveness of the questionnaire. According to the replies made by all 10 members, no major comments were made, except that some slight mistakes were found, which were corrected as a result. Importantly, the final version of the questionnaire included all amends suggested by the respondents.

The questionnaire in its final version, including categorical questions and question based on the Likert scale questions. Risk assessment in terms of the perceived level of impact and probability of the occurrence of a list of 30 risk factors in relation to the implementation process of green construction projects using a five-point Likert scale (1 = very low; 5 = very high probability and impact). The questionnaire was distributed to local stakeholders with experience in Kuwait's building and construction industry. Snowball and purposive or judgmental sampling techniques were used to maintain a high degree of legitimacy of the received data. To assist respondents and improve the response rate, a web based questionnaire was designed and the link was sent by email to all respondents. To maintain high degree of legitimacy of received data, a total of 210 questionnaires were distributed to the sample population and 132 questionnaires were collected from the respondents with a response rate of 63%. The data collected from the questionnaires was then collated in Microsoft Excel spread-sheets and data analysis was performed using SPSS software. Data gathered from the survey was analysed using the Relative Importance Index (RII). For this type of data, the mean and standard deviation of each factor are not suitable to determine the overall results because they do not reflect any relationship between the factors (Ghosh and Jintanapakanont, 2004). An RII value was calculated for the probability and impact of each risk factor. The same approach has been used by many researchers to analyse the probability and impact of risk factors [11-13]. RII is calculated using the following equation [14]:

$$\text{Relative Importance Index (RII)} = \frac{\sum_{i=1}^{5} a_i n_i}{5N} \qquad (1)$$

Where
a = the weight assigned to each response,
N = total number of responses,
n = frequency of each response,
5 = the greatest weight

The probability and impact of each factor is multiplied to obtain the degree of risk. The prioritised risk factors can be assessed further in order to conduct a quantitative analysis of the degree of risks. "The specific combinations of probability and impact lead to a risk being rated as ‘high’, ‘moderate’, or ‘low’ significance” [15]

4. Data Analysis and Findings

4.1 Respondents profile

The questionnaire survey forms were distributed to local construction stakeholders associated with the Kuwait construction industry. A total of 210 questionnaires were distributed and 132 completed questionnaires were received. Table 1 summarizes the respondents’ profile.

Table 1. Respondents' profile

Category	Respondents	
	Number	%
Business category		
Developer/client	33	25
contractor	13	10
Supplier	5	4
Owner	11	8
Academic/researcher institute	17	13
Facility manager	9	7
subcontractor	4	3
Consultant	40	30
Year of experiences		
< 5 years	33	25
5-10 years	48	36
10-15 years	25	19
15-20 years	13	10
>20 years	13	10
Type of organization		
Government sector	58	44
Private sector	74	56

The majority of survey participants, 30%, were consultants, while 25% were developers/clients, 13% worked for academic/research institutes, 10% were contractors, 8% were owners, 7% were facility managers, 4% were suppliers and 3% were sub-contractors The richer the experience of participants in the construction sector results in getting better information about the perceptions of risk for the construction and implementing the practices of green buildings in Kuwait. 35% of the respondents surveyed had between 5-10 years' experience in construction industry, 25 % had less than 5 years of experience in construction industry, 19 % had between 10- 15 years of experience in construction industry, and 10% respondents had more than 20 years of experiences. The results indicated that the majority of the respondents had been involved in two types of building project: commercial/office building and residential building. The results reveal that the majority of participants (56%) belonged to the private sector, whereas 44 % of the participants belonged to the government sector.

4.2 Risk Identification & Analysis

The respondents were asked to provide their perceptions on the probability of occurrence and level of impact for each of the identified risk factors associated during the process of implementation the practice of green building projects in Kuwait. A total of thirty risks were identified and derived through the literature review and categorized into the following group (Figure 3): Education Risk, Financial Risk, Performance Risk, Supply Chain, and Technology Risk [16-19]. The respondents were asked to rate probability of occurrence and the level of impact of the risk factors according to the following Likert scale: '1' very low , '2' denoting low, '3' denoting medium , '4' high, and '5' very high. According to [20], there are several criteria used in evaluating whether the level of any given risk is high or low, for example the probability of an undesirable occurrence, the degree of seriousness, and the resulting impact if that risk does occur. The survey participants were asked to gauge their perceptions on the probability of occurrence and the impact of the risk factors in figure 1.

Figure 1 Risk Factors

4.3 Reliability Test

To ensure the reliability of each factor, Cronbach's coefficient alpha was used to test the internal consistency among the items included in each factor [10].

Table 2 Reliability Statistics

Scale title	N of Items	Cronbach's Alpha
Probability factors	30	0.949
Impact factors		0.950

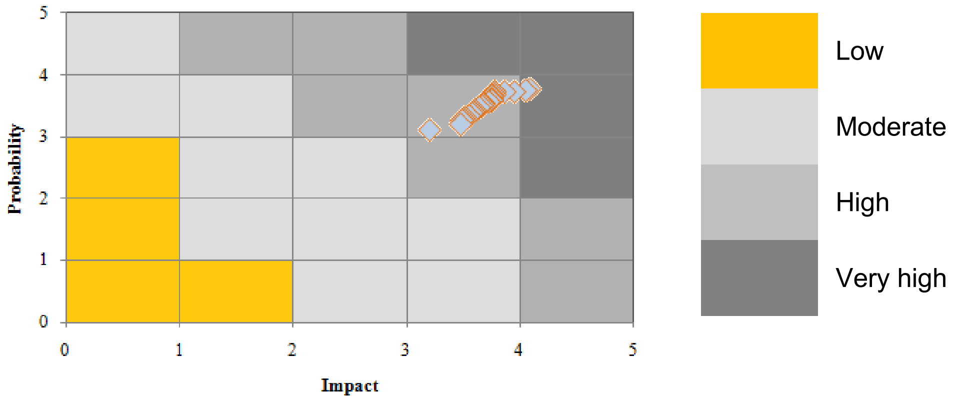
The results show that the internal consistency is 0.949 for the probability of risk factors whereas 0.950 is for the impact of risk factors. According to Pallant [10], the internal consistency is considered to be confirmed at the Cronbach Alpha of 0.7 or above. Therefore, both the values are at an acceptable level for making all factors reliable.

4.4 Risk Significance

The survey participants provided numerical scores that expressed their perception on probability of occurrence and level of impact of each factor to deliver green building project. For this type of data, the mean and standard deviation of each factor are not suitable to determine the overall results because they do not reflect any relationship between the factors [13]. Instated, the risk factors gathered from the survey were analysed statistically using Relative Important Index (RII). According to the RII, the risks indicated by the stakeholders were then ranked as the results are shown in the Table 3. According to risk rating values, the most significant risk identified was 'lack of knowledge and experience of site supervision' (RII = 0.609) followed by 'lack of expertise in designing green buildings' (RII= 0.608). Other important risk factors were 'Lack of knowledge of green building costs' (RII= 0.595), 'lack of technological sophistication and experience of individual team members' (RII= 0.572), and 'green building projects not achieving the designed green performance' (RII = 0.561).

To thoroughly evaluate construction risks, one must consider both the probability of the risk occurring and the impact that risk will have on the project objectives once the risk event occurs [11]. The risk probability and impact plotting matrix could be utilised to achieve the probability and impact of risk in a better way as shown in Figure 2. The plots on the matrix are from the calculated degrees of risk values shown in Table 3.

Figure 2 Probabilities - Impact Matrix



The matrix shows that the y-axis represents the value of probability whereas the x-axis represents the value of impact. The both end presents the scales from 1-5 where '1' shows lowest and '5' indicates highest value. It is observed from the matrix that all 30 risks are shown to be high as the probability is greater than 3 and the impact is between 3 and 5.

Table 3 Overall risk significance

		PROBABILITY		IMPACT		DEGREE OF RISK	
		RII	Ranking	RII	Ranking	Value	Rank-ing
E1	Lack of knowledge and experience of site supervision	0.746	4	0.817	1	0.609	1
E2	Lack of expertise of designing green building	0.752	2	0.808	2	0.608	2
E3	Lack of knowledge and experience of contractors / subcontractors	0.746	5	0.744	13	0.555	6
E4	Lack of knowledge of green building costs	0.756	1	0.788	3	0.595	3
E5	Use of untested materials, unknown quality of green materials	0.746	6	0.733	15	0.547	8
E6	Lack of commitment in the supply chain to go green	0.713	11	0.698	28	0.498	20
E7	Lack of technological sophistication and experience of individual team members	0.740	7	0.773	4	0.572	4
E8	Unfamiliarity with green concept , advantages and certification	0.719	12	0.750	8	0.539	11
F1	Lack of operational standards for new construction	0.706	17	0.710	24	0.502	19
F2	Poor management of green related information	0.625	31	0.640	31	0.400	31
F3	Availability of green materials	0.673	24	0.694	30	0.467	28
F4	Limit of green suppliers	0.660	27	0.702	26	0.463	29
F5	Lack of operational standards for new construction	0.740	8	0.733	16	0.543	9
F6	Product performance and reliability	0.723	11	0.733	17	0.530	14
F7	Default of a qualified subcontractor and challenge of replacing them with an-other qualified subcontractor	0.683	21	0.727	19	0.497	21
F8	Higher investment cost to go green	0.656	29	0.721	20	0.473	27
P1	Lack of knowledge of green building costs	0.713	16	0.754	5	0.538	13
P2	Quality of green materials	0.690	20	0.744	14	0.513	16
P3	Price inflation of construction materials	0.667	26	0.710	25	0.474	26
P4	Project no longer financially viable	0.715	13	0.717	22	0.512	17
P5	Inability to confirm the new specifica-tion	0.735	9	0.748	10	0.550	7
S1	Contract problems	0.681	22	0.748	11	0.510	18
S2	ability of products, systems and build-ings to perform in a green environment	0.725	10	0.748	12	0.542	10
S3	Failure to secure incentives and grants as part of overall project	0.658	28	0.731	18	0.481	25
S4	Projects not achieving the desired business case	0.698	19	0.754	6	0.526	15
T1	Green building projects not achieving the designed green performance	0.748	3	0.750	9	0.561	5
T2	Availability and use of technology suitable for green design	0.671	25	0.719	21	0.482	24
T3	Lack of shared information on green building	0.642	30	0.700	27	0.449	30
T4	Change in technologies due to green building	0.715	14	0.754	7	0.539	12
T5	Increased risk of delays because the building is green	0.679	23	0.715	23	0.485	23
T6	Cost of certification	0.702	18	0.698	29	0.490	22

5. Conclusion and Recommendation

Managing risks in construction projects has been recognized as a very important process in order to achieve project objectives in terms of time, cost, quality, safety and environmental sustainability. This study investigates the risks associated with implementation the practise of green construction in Kuwait. This paper presents the research results obtained through questionnaire survey conducted in Kuwait. A total of 30 key risk factors associated with implementation of the practices of green building were identified according to their value of risk impact and probability risk assessment. These significant factors fall into five major group categories: education risk, financial risk, performance risk, supply chain risk and technology risk. The Relative Importance Index (RII) for each probability and impact of risk factor were calculated based on the data collected through the s. The top five risk factors were found to be ‘lack of knowledge and experience of site supervision’, ‘lack of expertise in designing green buildings’ ,‘the lack of knowledge of green building costs’ ,‘lack of technological sophistication and experience of individual team members’, and ‘green building projects not achieving the desired green performance’. The probability and impact matrix show that the majority of risks are high (the probability is greater than 3 and the impact is between 3 and 5).

The results of the research confirmed that the implementation of the concept of sustainability and green practice is thus far limited within the Kuwaiti construction industry. It requires greater action and more strategies to improve and encourage implementation of the concept so that it can be applied effectively in future construction projects. As a matter of urgency, the industries should encourage the implementation and adoption of the concept of sustainability and green construction in the construction business. The roles of consultants, contractors, sub-contractors, architects and suppliers should be influenced by the existing market situation and by the client’s demand. In spite of all this, it is important to note that environmental awareness is a cooperative effort among all concerned. All stakeholders in the construction industry should be vigilant, conscientious and responsible enough to obligate themselves in encouraging each other in enhancing environmental awareness.

In order to achieve sustainability in the construction industry, awareness programs in respect of green practices and sustainability can play a vital role. Improving awareness and knowledge would make a massive impact to acceptance and increase the movement toward the implementation of sustainability and green building practice. This could be achieved through training seminars, workshops, and conference targeting different groups of construction stakeholders and end-users. Additionally, raising awareness could be achieved by introducing proper guidelines, tools or techniques based on prior research in order to make them more practical and effective.

The government bodies and professional institutes can help to increase the awareness level about green construction. Increased levels of cooperation and co-ordination, additional discussions, trainings, seminars and workshops are a must for directing different groups of stakeholders to improve their level of knowledge and awareness. It is a requirement of the times to successfully promulgate the fundamental benefits, values, contribution to society and long-term cost paybacks of green buildings to the users in order to spread proper awareness. The higher awareness levels of end-users will create a higher demand for green buildings. The concept must be aligned with the growing concept of sustainability and necessary changes need to be made for this purpose.

In order to overcome the existing challenges that are revealed in this research in relation to the perceived risks, such as lack of experts in green practices, the lack of green suppliers, and lack of green technology, the construction stakeholders in Kuwait can start the initial green building movement using existing materials and experts. Building fabric components such as advanced glazing, shading devices and insulation should be specified as a matter of routine in order to achieve significant reductions in annual cooling loads. This incremental method of adoption and implementation will gradually assist green building practices towards becoming the accepted and common practices of the construction industry.

In another hand, the government role is vital in regulating energy prices to encourage green building construction and make it profitable. The government should formulate regulations, set standards and mandatory requirements for the regulation of green building construction. This commitment from the government will encourage the progressive stakeholders by eradicating uncertainties in the construction market by providing opportunities and offering a better more attractive working environment for participants of green building stakeholders. The regulatory processes, public policies and other procedures decide if developers integrate green building practices and design into their projects. Occasionally existing rules and regulations are not adjusted according to the latest practices by a number of authorities, and this causes difficulties in permitting such projects and can create regulatory blockades. In this way standards and codes can work as a barrier to the adoption of the concept of green buildings. On the other hand, they can also be used to promote the concept.

The government should provide opportunities for developing green building technology and increase available knowledge to allow for lower initial and operational costs for green building projects. The government could also offer incentives and rewards to stakeholders to make sustainable green building economically viable and a more attractive prospect. This incentive could include subsidies awarded by the government, financial discounts, pre-tax loans and other financial incentives for construction of green buildings should be considered by the government. This research discusses the risks associated with the implementation of the practices of green construction from the construction stakeholder perception. However, the scope of study is limited to Kuwait; it might be useful if, through future research, the results of this study can be compared and evaluated with the results of other researchers conducted in different countries. To minimize the chances of failure of the green construction projects, the significant risk factors as revealed in this study should be properly handled when managing risks. Further research could be undertaken to develop management strategies to minimize and control risks related to green building projects.

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Shenzhen's New Energy Vehicles and charging infrastructure – policies, instruments and development

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Summary

Billions for green growth. Shenzhen, one of China's richest cities and home of New Energy Vehicles (NEV) producer Build your Dreams (BYD), will invest 5 billion Yuan (804 million USD) in NEV development by the end of 2015. Especially for pure electric vehicles. The megacity is using electric mobility as an instrument to reduce carbon emissions while creating economic growth. Against the background to the negative effects of traffic-related air pollution in China, the key is to promote sustainable transport. Comprehensive solutions have been adopted in several low-carbon city projects that prioritize Transit-Oriented Development (TOD) strategies. From 2011 to 2020, Shenzhen wants to reduce carbon emissions by 40-45 %. To activate green public and private investments, the city leaders formulated several policies for New Energy Vehicles (NEV) and charging infrastructure promotion and application. With the development of existing fast charging networks from 1,100 to 1,800 piles for commercial NEVs and slow charging piles in 5 % of all residential and 10 % of all public parking spaces, policymakers hope to overcome the bottleneck constraint in a lack of charging infrastructure. From 9,392 NEVs by the end of 2014, an additional 15,000 new energy taxis, buses, municipal vehicles, e-car-sharing services and private NEVs are to be subsidized in the coming years. Several top-down policies support these goals, for example purchase or tax incentives connected with sanctions for fuel car number plates. Shenzhen's challenge is to encourage citizens to use NEVs while finding the balance between economic development and environmental protection.

Keywords: New Energy Vehicle (NEV), charging infrastructure, sustainable transport, policies & instruments, Shenzhen

1. Introduction

Electric mobility provides a strategic technological solution towards sustainable transportation systems - particularly for China's urban growth. Therefore, the Chinese government is pushing the rapid development of New Energy Vehicles (NEV). China's cities suffer from high levels of air pollution, and NEVs are needed in order to reduce carbon emissions by 40-45 % by 2020, compared to 2005 levels [1]. Eighty-eight Chinese cities and 26 provinces are part of the Chinese NEV demonstration regions [2]. These regions serve as test sites for NEV policies and instruments. Besides Beijing and Shanghai, Shenzhen is one of the top cities for NEV development.

Founded in 1980 as China's first special economic zone, Shenzhen is well known for its rapid and successful development. The implementation of NEVs in public transport is connected with low-carbon plans that follow the guidelines of the 12th Five-Year Plan. The 35-year-old megacity has more than 10 million inhabitants and approximately 3 million cars, as of the end of 2014 [3]. With more than 10,000 NEVs, the southern Chinese metropolis is one of the leading cities in the application and promotion of electric vehicles worldwide. In 2015, Shenzhen's target is to increase the number of NEVs to 25,000 NEVs [4].

Shenzhen's construction land is still expanding and sustainable solutions are needed. Several new urban development projects that integrate electric mobility from the beginning stages of the planning process were started in recent years. TOD strategies, a city of short distances and green transport concepts have been used as examples from international good practice cities like Copenhagen or Seoul. The 'International Low-Carbon City (ILCC)' in Longgang District, in cooperation with the EU and Dutch government or 'Qianhai Shenzhen-Hongkong Modern Service Industry Cooperation Zone of Shenzhen', are popular examples, but are still under construction.

However, in existing and new development areas there are still many constraints. The lack of charging infrastructure, imperfect auxiliary facilities, incomplete supporting policies, inadequate business models, insufficient enterprise innovation or a lack of highly skilled labour were identified as main constraints by municipal leaders. To overcome these bottleneck constraints, in January 2015 the Shenzhen municipal government formulated very ambitious policies to improve municipal instruments for future NEV development. These policies are covered by a 5 billion Yuan (804 million USD) fund in the form of a municipal incentive and subsidy to enhance full electric vehicles, a citywide charging network and a unified charging standard. This funding is connected to the two-year high-tech plan by the National Development and Reform Commission to create globally competitive homegrown brands in six industries, including electric cars [5].

The first hypothesis assumes that Shenzhen and the central government set up strong policies to successfully integrate NEVs into the public transport system by 2020. The hometown of battery and NEV manufacturer BYD has strong economic interests and uses green public procurement to replace the public buses, taxis and municipal fleets with electric vehicles. Today, most NEVs belong to public transport. The second hypothesis suggests a gap between planning instruments and realisation in new and existing urban development projects. On the one hand, the hierarchical top-down planning is well organized, a lot of money is available and construction phases proceed very fast. On the other hand, charging facilities are not included in urban planning and charging facility land cannot be guaranteed. This inhibits public and private investment in charging facility construction. On-site research showed that many slow charging facilities are rarely or not used. This leads to the third hypothesis that a number of barriers affect the private NEV market. As in other regions all over the world, private users are reluctant to use NEV technology. Purchase or tax incentives connected with sanctions for fuel cars are the Chinese methods to solve this problem. Electric cars and buses that use green energy reduce carbon emission in the field of sustainable transport. The integration of new mobility concepts requires new methods and flexibility in urban governance and planning processes. Stakeholders, planners and the scientific community have to consider how electric mobility changes the urban landscape. Fast growing Chinese megacities have the opportunity to take a leading position in the field of electric mobility. Shenzhen can be a best practice for other megacities if the policies and instruments prove successful in future. The challenge is to change citizens' transportation preferences while finding the balance between economic development and environmental protection.

2. Methodology

This paper firstly outlines the context of Shenzhen's NEV and charging infrastructure development until 2015, and summarizes the current policy targets and instruments. In particular, an examination of 'The Several Policies and Measures of New Energy Vehicles' Promotion and Application' and its 'Working Plan to Develop New Energy Vehicles in Shenzhen (2013-2015)' is included, outlining and discussing NEV instruments that will be applied on municipal- or micro level urban development projects. The conclusion gives some projections for future development.
Based on a quantitative data collection from relevant urban development projects in Shenzhen, the main actors in the field of electric mobility and urban development were identified. In cooperation with Peking University Shenzhen Graduate School (PKUSZ), more than 25 qualitative expert and stakeholder interviews were done in spring 2015 in Shenzhen and Guangzhou. The language difficulties and the loss of details during translation are not to be underestimated in the Chinese context. The following forms of data collection can be distinguished between secondary research (desk research) and primary research (field-research):

- Expert and stakeholder interviews with group discussions (and professional interpreters)
- Translation and analysis of policies, planning documents and official statistics
- Leap-frog method (inventory analysis, observation, site visit)

3. Results from Shenzhen

3.1 Organization and development

The municipal government set up the 'Shenzhen Leading Group Office of Promotion and Application of New Energy Vehicles' (SZLGO) as responsible policymaker for NEV and charging infrastructure development. The SZLGO is guided by the Shenzhen Development and Reform Commission and gets support from the Municipal Science, Technology and Innovation Commission, the Municipal Transport Commission, which is responsible for the application, and the Finance Commission. Other municipal departments like the Housing and Construction Bureau or the Planning, Land Use and Resources Commission are, for example, responsible for supporting the construction of charging infrastructure. The mayor and vice-mayor of Shenzhen make final decisions in a top-down hierarchy. The government has worked closely with BYD since 2004, which is Chinas biggest NEV producer. Its competitor, Wuzhoulong Motors, is the second biggest manufacturer for Shenzhen's NEV fleets. BYD is at the top of the supply chain of the Shenzhen NEV Union. Company representatives are leading negotiations with municipal policymakers to establish a win-win situation for all actors.
According to Shenzhen's working plan to develop NEVs, the plan is based on three principles: (A) Successful demonstration and promotion, (B) rapid industry development and (C) the steady development of charging infrastructure, planning instruments and business models.
(A) By December 2014, there were 9,392 NEVs on Shenzhen's roads. This number includes 850 full electric BYD e6 taxis, 1,253 pure electric shuttle buses, 26 pure electric mini buses and 1,771 hybrid buses that are omnipresent in public transport. In addition, there were 4,910 private full electric and hybrid vehicles, 62 fuel cell vehicles and 520 full electric municipal police cars. With a cumulative distance travelled of more than 800 million km, over 220,000 tons of CO_2 were saved [6].
(B) Shenzhen has strong industry goals. The promotion of the NEV industry should help reduce air pollution and greenhouse gas emissions, improve energy security and upgrade China's industry with economic growth into the 'third industrial revolution' [7].

(C) Shenzhen has 81 fast charging stations (DC flow) for commercial use. Seventy-four are used by e-buses and seven used by e-taxis. The fast charging duration is about 100 Minutes. More than 3,000 slow charging piles (AC flow) were installed mainly for private maintenance around the whole city. The charging duration lies between five and eight hours, depending on the charging facilities. Security systems, business operation models for NEV buses and taxis were improved to a mileage of more than 250 km for buses and 300 km for taxis now.

3.2 Policies

Shenzhen has an open NEV development strategy and comprehensive policy support. That means the development of hybrid-, fuel cell- and full electric vehicles can be government-funded. The use of plug-in hybrids is only an interim solution to follow the municipal's green strategy. The future target is to change NEV fleets to full-electric models [8]. Shenzhen belongs to the eight low-carbon pilot cities and five provinces that implemented a low-carbon development plan, supporting policies, develop low-carbon industry, establish CO2 emission statistics and encourage low carbon lifestyles and consumption [9]. The target for 2020 is no CO2 emissions in the public transport sector, connected with a gradual transformation towards commercial and private NEVs. Since 2009, several policies and subsidies like the 'Shenzhen Energy-Saving and NEV Demonstration Program (2009-2012)' and the 'Shenzhen Private Purchase NEV Pilot Subsidy Plan' covered by 5.6 billion Yuan in funding were implemented [10]. To compile overall national guidelines Shenzhen follows 'The 12th Five-Year Plan for the National Economic and Social Development', national industry plans known as 'The 12th Five-Year NEV Industry Development Plan', or 'China's Policies and Actions Addressing Climate Change' from 2011. Several upgrading incentives out of the '863 R&D Program' since 2001 or the national application demonstration project 'Ten Cities, One Thousand Vehicles Program' provide a good policy environment mainly for NEV industry development. The guiding concept for further NEV development in Shenzhen is based on the national 'Instruction about Accelerating NEV Demonstration and Application' and the national 'Development Plan of Energy-Saving and NEV Industry (2012-2020)' by the State Council. Out of these documents, the SZLGO prepared over the course of two years the central guideline 'The notification of Several Policies and Measures of New Energy Vehicles' Promotion and Application', which will be financed by the 'Shenzhen Energy Saving and New Energy Vehicle Demonstration Promotion and Support Fund (2013-2015)' covered by 5 billion Yuan [11]. This funding is covered by the good financial resources by the municipality of Shenzhen. It aims on the key areas of NEV industry development: purchase incentives, charging infrastructure construction, standardization and the improvement of policies and regulations. The following policies summarize the most important NEV regulations and connected policies on the local level.

Policies and regulations for NEV development in Shenzhen	Connected plans that include NEV development in Shenzhen
• Shenzhen Energy-Saving and New-Energy Vehicles Demonstration Programme (2009-2012) • Shenzhen's New Energy Industry Development Planning (2009-2015) • The Notification of Several Policies and Measures of New Energy Vehicles' Promotion and Application (2013-2015) • Shenzhen Energy Saving and New Energy Vehicle Demonstration Promotion and Support Fund (2013-2015) covered with 5 billion Yuan	• Low-Carbon Development Plan for Shenzhen (2009-2020) • Shenzhen Clean Transport Plan (2012-2014)

Fig. 1: Central NEV policies and guidelines from Shenzhen Municipal Government
Source: Own compilation

It is obvious that the policy set up is guided by economic interests. The implementation in sustainable urban development strategies and low-carbon plans is just in the testing and starting phase. An integration of charging stations into Shenzhen's masterplanning is still missing. It should be done a new plan or an integration into Shenzhen's 'Vehicle Petrol Station Plan' in future. Shenzhen is since its funding an experimental zone for central governmental reform projects. High planning standards and practical concepts from Hongkong and western countries could evolve [12]. In comparison to other Chinese cities, the rule of law, containment of corruption and other sustainable approaches have more influence on local policies. The city act as national model region with its systematically approach of NEV promotion and application in public transport and municipal fleets, the evolution of an NEV innovation system, rapid industry development and the construction of charging infrastructure. Concrete evidence is that municipal and private fleet providers should meet their specified quotas for NEV integration. The NEV manufacturers should be able to lower sale prices by achieving economies of scale. Related to article two and three of Shenzhen's policy document [13], public transport bus, taxi and municipal fleets should include no less than 70 % NEVs. Sanitation trucks should include no less than 50 %, small freight vehicles; commuter and tourist buses should meet a 30 % NEV quota. Individuals and companies are encouraged to purchase NEVs.

3.3 Instruments

Instruments for electric mobility can be defined as the municipal action as configurer, licensor, supporter, operator and user [14]. The Municipality of Shenzhen developed a wide range of instruments to implement NEV technology systematically to reach the number of 25.000 NEVs. While the public transport sector and municipal fleets receive different subsidies depending on the vehicle length, range or NEV-type, whereas private enterprises and private persons receive various financial and tax advantages, depending on the range and NEV-type. For example, Taxi service companies benefit by purchasing NEV taxis and receive a subsidy of 55,800 Yuan per NEV taxi. By end of 2015, the purchase of 4,000 pure-electric taxis will have been funded by the government. The subsidy amount is based on the sale price of the electric car. For the 2014 to 2015 period, the government expected that 10 to 15 % of the taxi companies, which are approved for the special economic zone in Shenzhen (red taxis), will have replaced some of their fuel cars with electric vehicles. Based on the full electric BYD model e6, there is a cost advantage for local taxi companies around 20.000 Yuan per vehicle because the taxi licence for pure electric taxis is free. Transportation authorities of the districts are responsible for specific programmes.

Electric carsharing companies should extend their rental service for the large scaled application, charging and maintenance of NEV vehicles. With a target of 2,000 NEVs, the government wants to foster this transportation model to reduce traffic congestion. Since June 2015, the 'Shenzhen Jinqianchao Electric Vehicle Leasing Service Co.' introduced the first electric carsharing stations, including Shenzhen Airport and Shenzhen North Railway Station [15]. More suppliers will follow. Private NEV buyers and private companies receive state and local subsidies upwards of 114,000 Yuan (17.900 USD) per vehicle [16]. No other Chinese city gives more subsidies for NEV users.

Besides the push of charging infrastructure development (discussed in 4.1), there are other non-monetary incentives and restrictions. With a limit of 100.000 car number plates, Shenzhen government started a car plate lottery with a NEV quota of 20.000 car number plates end of 2014. Motorized bicycles were prohibited more than 10 years ago. Lifestyles in using electric bicycles are very popular. Based on the legally binding policy structure, there are various instruments that can be identified for the development of municipal NEV and charging infrastructure. This makes the city leaders confident they will be able to close the gap between economic development and environmental protection. Up to 25 instruments are formulated in the following table.

Category	Instrument
Public transport and municipal fleets	Subsidy for Public Transport Companies (e-Bus and e-Taxi)
	NEVs for the municipal service and special fleet (Sanitation, Police, Logistics, e-Carsharing)
NEV purchase incentive	Subsidy to manufacturer and supplier
	National and local subsidy to private and commercial buyer
Other monetary incentives	Tax incentives
	Toll road privilege
	Privileges for accident insurance
Non-monetary incentives	Security system
	Privilege for parking
	Car number plate lottery (20,000 NEV)
	NEV service platform
	National NEV traffic management policy
Penalties	Number plate restriction for fuel vehicles
	Prohibition of motorized bicycle
	Prohibition of electric bicycles with maximum speeds greater than 20 km/h speed

Category	Instrument
Charging infrastructure	Construction of charging piles
	Construction of large-scale charging stations
	Implement site location planning
	Definition of construction standard
	Set up operator service
	Public parking lots (existing > 10%, new 20 %)
	Residence area parking lots (existing > 5%, new 20 %)
	National charging standard
Other infrastructure	Power supply network
	Technology research center
NEV innovation system	Creation of attractive frameworks for NEV manufacturing and battery technology
Industry development	Free or cheaper land for industry development
	Industrial cluster promotion

Fig. 2: Instruments for NEV and charging infrastructure development in Shenzhen
Source: Own compilation

4. Discussion

The policies and instruments mentioned are the key framework for NEV development in Shenzhen, but the urban space in this fast growing megacity is very heterogeneous. Whereas overall urban planning follows strong top-down decisions led by the government [17], districts governments act a bit more independent. Out of this reason, the implementation process will be timed differently, depending on the local priorities. Some new city areas are designated as application areas, while some others, especially the urban villages, are more separated from this development.

4.1 Municipal level

On the municipal level, Shenzhen's transportation circulation system is used by 10 million people per day. Among them, 6 million travel by bus, 3 million by metro and 1,2 million by taxi. Taxis and buses account for 1,1 % of all vehicles in Shenzhen, but they are responsible for 20 % of traffic-related air pollution. For that reason, the municipal leaders decided to start with the promotion and application of electric vehicles in the public transport sector. Today, the megacity is a global pioneer in this sector. The omnipresence of e-taxis and NEV buses are a good marketing tool to strengthen political support and acceptance among citizens for electric mobility. Many years of experience in this field are reflected in the core content of these policies. There are nearly 4,000 NEVs in the public transport fleet, including the 1,600 pure electric buses and 850 pure electric taxis on Shenzhen's roads. This is combined with 830 km special bus lines, making it the second largest network after Chengdu in China. By the end of 2015, the government will have procured 1,500 pure-electric buses, increasing the total number of NEV buses to 6,650. This will be 44 % of the total fleet of public transport buses running in Shenzhen [18].

Nevertheless, there are contradictions between large-scale expansion of the fleet with NEVs and the limited construction of charging facilities, the inadequate supporting policies and the inadequate business models. For that reason, the Shenzhen Leading Group Office improved policies. As a result, the state owned service providers for charging infrastructure like POTEVIO will construct nine comprehensive large-scale NEV bus charging, maintenance, and parking service centers for 4,000 NEV buses during the 13th Five Year Program from 2016 to 2020 [19]. District governments are responsible for the selection of urban space for charging stations, but available land is limited. From 950 sq kilometers allowed land for development, there were only 140 left in 2010 [20]. This land is mainly occupied by other commercial or residential use. There are projects with implementation challenges, especially for private users. After 2010, the government selected 14 residential areas in which to integrate hundreds of slow charging facilities. On-site research performed by the authors showed most of these piles are not in use or do not exist. The main challenge identified by the government was the inadequate integration of charging facilities in urban planning. For that reason, land for charging facilities cannot be guaranteed and investment is constricted. Furthermore, there is a shortage of land for construction and it is almost impossible that undeveloped land can be used for charging infrastructure. This inhibits investment in charging facility construction. Therefore, policymaker decided the constructions of slow charging facilities should cover no less than 5 % of parking in existing residential areas, and no less than 10 % of parking in existing public parking lots [21].

While private NEV owners mainly use slow charging facilities, fast charging is just for supplementary use. Slow charging should be included in the standard of new construction design, green building design standards and energy assessment specification, in order to ensure adequate power capacity. Due to the successful application of NEV buses and taxis, fast charging piles for commercial NEVs are frequently used. Over the last years, the municipal leaders identified the lack of charging infrastructure as the main bottleneck constraint. They decided a spatial distribution within a radius of 5-10 km over the city. In total, 1,800 charging points must be built [22]. By the end of 2014, there were already 1,100. Therefore, the districts have to build 700 in one year and give franchise to companies like POTEVIO for maintenance. According to urban planners from Shenzhen, there are five ways to integrate charging infrastructure in urban planning: the creation of statutory plans for new construction areas, the addition into public parking space, the alteration of residential area planning, an addition to fuel stations without changing the land use policy or the expropriation of temporary land [23]. The SZLGO tries to fasten the construction process while charging operators do not need to apply for approval of land use planning.

4.2 Micro level

On the micro level, there are some outstanding projects of national significance, like the 'Qianhai Shenzhen-Hongkong Modern Service Industry Cooperation Zone of Shenzhen'. More than two kilometres of land were captured from the sea to develop a new city center. Three hundred electric carsharing cars will be implemented there [24]. Nine metro and railway lines will connect an intermodal TOD concept that includes NEVs to promote a city of short distances. The new public transport traffic hub will connect Guangzhou and Hongkong on a new north-south axis. Here, urban planners take a reduction of individual transport up to 50 % into account. Another important project is the Shenzhen International Low-Carbon City (ILCC) in Pingdi (Longgang District). This flagship project, based on the 'Sino-EU sustainable urbanization cooperation partnership agreement' from 2012, is located at the intersection of three cities: Shenzhen, Huizhou and Dongguan. It aims on the integration of low-carbon technologies like electric mobility. The 53 sq km urban development zone has 160,000 inhabitants and is relatively low-income area when compared to the average GDP-level of Shenzhen. The showcase project has lower land prices than other urban areas. The city leaders have integrated TOD concepts and charging infrastructure from the very beginning to attract highly skilled workers and low-carbon investments. The goals for traffic development are mixed use, the optimization of the public service system, reduced walking distances for residents, priority to public transport and emphasis on the design of pedestrian zones to encourage low-carbon transportation [25]. Furthermore, the ILCC will use green energy, like solar panels, to power the charging infrastructure, which is not standard in Shenzhen. It is important to keep in mind that nuclear power is included in the new energy sector which represent up to 60 % of energy production in Shenzhen [26]. The comprehensive plan of land use density (2010-2020) shows the spatial distribution of Qianhai and Pingdi urban development projects and the very high density (dark red areas) of Shenzhen's urban regions.

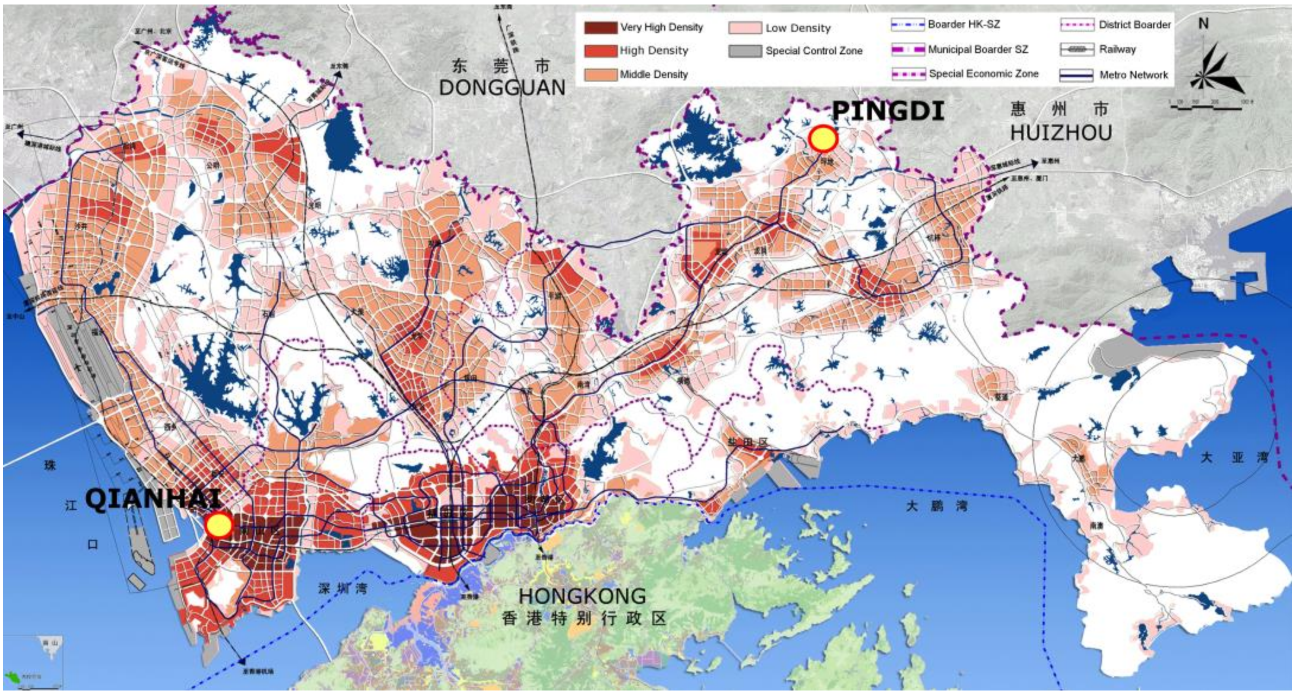

Fig. 3: Shenzhen land use density map (2010-2020) including the location of Qianhai and Pingdi
Source: [27] with own illustrations

Qianhai, Pingdi and many other new development projects are already under construction. While Qianhai seems to gain from big private investments, Pingdi is in a half-stagnant status. Further evaluation of the effects on urban development has yet to be performed.

5. Conclusion

Shenzhen is a leading city as a test laboratory for NEV policies, instruments and development worldwide. Investments in NEV and charging facilities as a driver for industrial development are exemplary. The megacity focuses on sustainable transport solutions, where comprehensive NEV strategies are seen as a complementary instrument to make private and public transport cleaner. Vehicles should not be replaced 1:1 from fossil fuel to NEV. Using a mix of restrictions for fuel cars and incentives for NEVs and charging infrastructure, the municipal leaders place pressure on district authorities, industry and private individuals to implement this technology. If municipal leaders follow the target to promote public transport introduced in 2010, NEVs in the form of electric carsharing can be used to reduce traffic congestion, while limiting harmful emissions. The use of green energy is rising, but as long as nuclear power is considered 'green' energy, it is difficult to compare emissions reductions successes with similar programs in countries that do not consider nuclear power 'green', for example, in Germany. NEVs should be a complementary part of an efficient urban transportation system in a city with short distances, where walking, bicycle, electric carsharing and public transport are promoted as well. This is only possible if a private market can be activated and citizens of Shenzhen can raise their affinity for the use of electric cars. While implementing the new technology in urban development areas, there are still many of contradictions. Limited experience, mismanagement or the shortage of available land for charging infrastructure are challenges the city faces. The availability of billions for 'green growth' is a step in the right direction for a Chinese megacity like Shenzhen. However, it is only one part of what should be a comprehensive system where stakeholder, commercial and private users follow a unified path. Future research may show which instruments work and which have to be adjusted.

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Single family home stocks in transition - implications for urban resource efficiency

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Summary

Single-family homes (SFH) – that make up about 65% of the residential building stock in Germany – have high potential to improve resource efficiency of urban development. At the same time, we observe indications, that demographic change and change in user preferences may lower the demand for such dwellings. In particular, regions with population decline and economic shrinkage are facing the risk of growing vacancy rates in single-family home neighborhoods. Considering the generally given higher resource intensity of SFH stocks, this potentially leads to significant inefficiencies of infrastructures, material and land consumption, which challenges the implementation of sustainability goals of resource efficiency and land use reduction.

Keywords: Demographic change, resource efficiency, settlement structures, built environment, Single-family homes

1. Introduction

In many countries, single-family homes (SFH) constitute the majority of residential buildings. In Germany, 66% of the residential building stock is made up by SFH. SFH are traditionally in great demand, and in 2011, more than 50% of the population in Europe lived in SFH. For some time already, increasing indications can be found, that this segment of the housing stock is under pressure. Economic and financial crises, demographic and social structural change, and changes in user preferences, are raising new challenges to it. Outside core regions of economic growth, stagnating or dropping prices, difficulties in selling, and even vacancies, are no longer a rarity. Nonetheless, these developments, and the possible consequences connected with them, have hardly been investigated in terms of sustainability dimensions, including *economics* (e.g. loss of equity/capital for the private owners and potentially resulting transfer costs for municipalities), *ecology* (e.g. inefficiencies in terms of energy, land and material use), *settlement-structure* (e.g. the sustainability of residential service facilities or the attractiveness of the residential environment), or the *social* situation (e.g. down-trading of neighborhoods, or loss of relevance for retirement provision). While multi-family residential buildings (MFH) enjoy a high level of attention from residential policy-makers and the housing industry, the developments in the area of the SFH segment, with its small scale private ownership structures – approximately 90% of these buildings are user-owned – is prominent neither on the academic nor on the political agenda.

Against this background, the research presented here aims to systematically describe and analyze the situation for different SFH stocks along the above sketched dimensions and to shed light on potential future development scenarios. The paper presents initial results from baseline research which was undertaken on development trends described in existing literature and preliminary assessments of possible implications for resource use.

2. Methodology

The ongoing research was started with a literature review on development trends for the SFH stocks. In addition, statistical analysis of census data and generic resource intensity data [1] as well as case study visits were combined into an explorative description of the status quo and to generate initial estimations of resource consumption implications.

3. Results

3.1 General issues and trends of change in the field of building and housing

Under the notion of demographic change, usually a quantitative change of the number of population, a changing age structure and migration issues are discussed (e.g. [2]). Particular challenges for Germany arise from the envisaged overall decline of population, the ageing of the population (people getting older and less children born) and from regional misbalances in population caused by regional out migration. The latter in particular in East Germany. In addition to the demographic factors socio-cultural factors like changing user preferences and patterns of consumption apply, which partly are closely connected to demographic changes as for example accessibility demands of ageing home owners. Structural effects, like the reduced number of school years or the abolition of mandatory military service may cause further changes, e. g. in terms of a peak of students competing on housing markets. Finally socio-economic context conditions contribute to changes on the housing market, such as changes in working conditions and cultures but also the crisis on real estate and financial markets.

3.2 Drivers and trends for the development of single family home stocks in Germany

Focusing on the SFH stocks, a growing number of indications can be derived from literature for potential relations between general trends and the development of this sector. Such indications for change can be structured along three possible general trends: 1. a decrease of demand for existing SFH, 2. the abandonment of the use of SFH by the former users and 3. the stabilization of demand for existing or new built SFH.

3.2.1 Decrease of demand for existing SFH

Looking at the demographic development the traditionally main user group for SFH – households in the life-phase of family formation and ownership acquisition between 30 and 45 years of age –

must be expected to decline due to the entrance of cohorts with low birth rates to the market [3; 4; 5; 6].

This trend is at least regionally enforced by a general decline of demand due to population shrinkage as a result of out-migration (e. g. [7; 8; 9]). Occasionally even abandonment of whole settlements – “de-settlement” – is discussed [10; 11]. The trend for smaller households with one or two persons [12; 13] also challenges traditional expectations for SFH demands, and seems to rather enforce the demand for ownership in apartments in particular in metropolitan centers [14]. This is driven further by insecure employment conditions and high demands on professional mobility [6; 15], which will lead to critical reconsideration of the ownership of property. Another relevant issue is framed by the notion of re-urbanization. Even if this cannot be considered a general trend [16; 17; 18], there are indications for a lower attractiveness of suburbia in particular for younger households and also for a growing orientation towards the urban centers by the elderly [19]. Heirs of aged households often are not interested in moving into the SFH themselves when receiving their heritage because – being 50+ of age themselves – they usually already built their own home [8; 20] – if they are opting for SFH at all. The experience of SFH real estate property considerably losing value during the real estate crisis relativizes the long unquestioned motive to build SFH ownership as part of retirement provision [21; 22]. In addition changing life styles like the “25-hours-society” [23] go along with changing user demands for example with respect to the availability of services and facilities in the housing environment [18; 24; 25; 26; 27] which may not be available in typical suburban SFH neighborhoods. To the contrary in ageing neighborhoods the relation of the life cycles of the users and refurbishment cycles may lead to a downward spiral of devaluation of the neighborhood if the users “wear out” their property instead of undertaking necessary maintenance [28; 29]. This problem is increased by the often outdated technological standards of such SFH – for example in terms of energetic properties – that lead to considerable costs of refurbishment measures [5; 20; 30]. This may cause a situation where cities are confronted with a rising supply of SFH with considerable market disadvantages juxtaposed by an ever lower level of demand by traditional user groups.

3.2.2 Abandonment of the use of SFH

In an ageing society the most natural reason for the abandonment of the use of SFH is the death of the former users without devolution of the use to heirs or other new users. This is a scenario that becomes particular relevant with the ageing baby boomer generation [31]. In addition there are also indications for a growing number of seniors – including such owning SFH property – that opt for a change in residence even at a higher age [23; 32] either to live with their children [33], or to move into the city centers [19; 34] although the latter cannot yet be considered a major trend [35; 36]. Elderly SFH households may even leave their homes and opt for a new built SFH which then might be smaller, closer to the city and better accessible as for example a bungalow style building without stairs (oral communication from case study visits).

3.2.3 Stabilizing SFH demand (existing and new built)

Despite of the above described trends and although this attractiveness may slightly decline [26], the housing model SFH generally is still highly attractive for large groups of households [13; 14; 18; 37] with used buildings gaining importance [13; 38]. For the inhabited stocks the growing risk of poverty of seniors [23] may force poorer households to stick to their property and “wear it out” [28]. Also the financial instrument of reverse mortgage may play an increasing role [39]. In addition, lower prices and the additional factor of low interest rates may enable new user groups to enter the market, thus contributing to ease the situation. Examples are e.g. low income households [40; 41], elderly two person and single households [32] even building a second time as already mentioned above, and better off heirs looking for (comparably safe) investment options [42; 43]. In particular in metropolitan regions also larger family households, that have a hard time to compete on tight rental markets [33], may opt for suburbia and there increase the demand for comparably affordable SFH property. Among these also migrant households may gain importance as SFH demanding user groups since they adopt traditional life styles, form larger families and catch up in terms of home ownership [5; 26; 44]. Furthermore and although currently 90% of these buildings are user-owned, the use of SFH is not restricted to ownership. Renting in the SFH segment is still a niche-product [5], but may gain importance in particular with investment groups buying larger SFH portfolios and renting them out.

3.2.4 Vacancy rates: Status quo

Based on German census 2011 data for the single family home stocks an average vacancy rate of 2,2% can be calculated (market mobility reserve not included), ranging from 0,7% to 5,3% for different construction periods and compared to 5,4% vacancy in multi-family houses (Fig. 1).

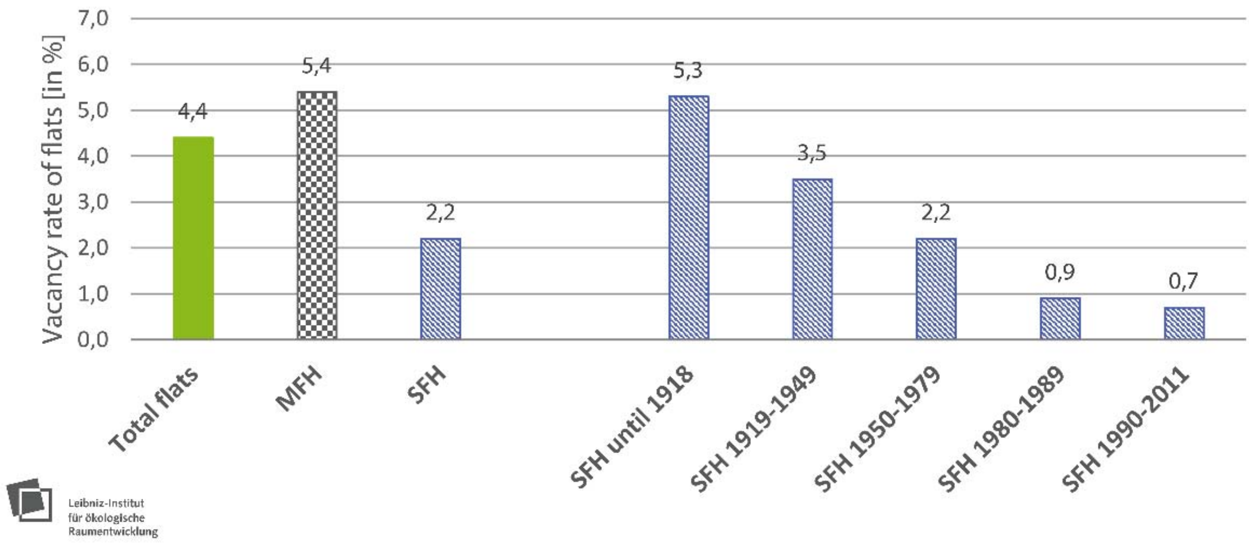

Fig. 1: Vacancy rates for flats in MFH and SFH in total and for different construction periods based on German census 2011 data (without market flexibility reserve)

On the first glance, a vacancy rate of 2,2% seems moderate, compared to 5,4% vacancy of flats in multi-family houses. However, vacancy of SFH can locally already today reach up to 10% in less dynamic regions. Also, due to the generally considerably higher resource intensity of single family homes even lower vacancy rates can add up to higher waste of resources. This is discussed in more detail in the next paragraph (resource intensity calculations based on [1]).

3.3 Implications for resource use

It is no secret that the single family home itself is a resource intensive type of housing, in particular from an urban development perspective with the related infrastructure considered. Besides an up to 5 times higher specific material input for the building itself, SFH neighborhoods tend to have a considerably lower urban density (calculated as FSI = gross floor space in m² per net residential land in m²) spelling out into much higher land uses and less efficient infrastructure in terms of costs as well as materials used. Assuming an average household size Fig. 2 shows the material intensity per resident (“material rucksack”) for different building types and settlement structures for synthetic neighbourhoods with 100 buildings. It is one striking result, that for detached SFH roughly 50% of the material input used for the building has to be added in order to take the related infrastructure into account.

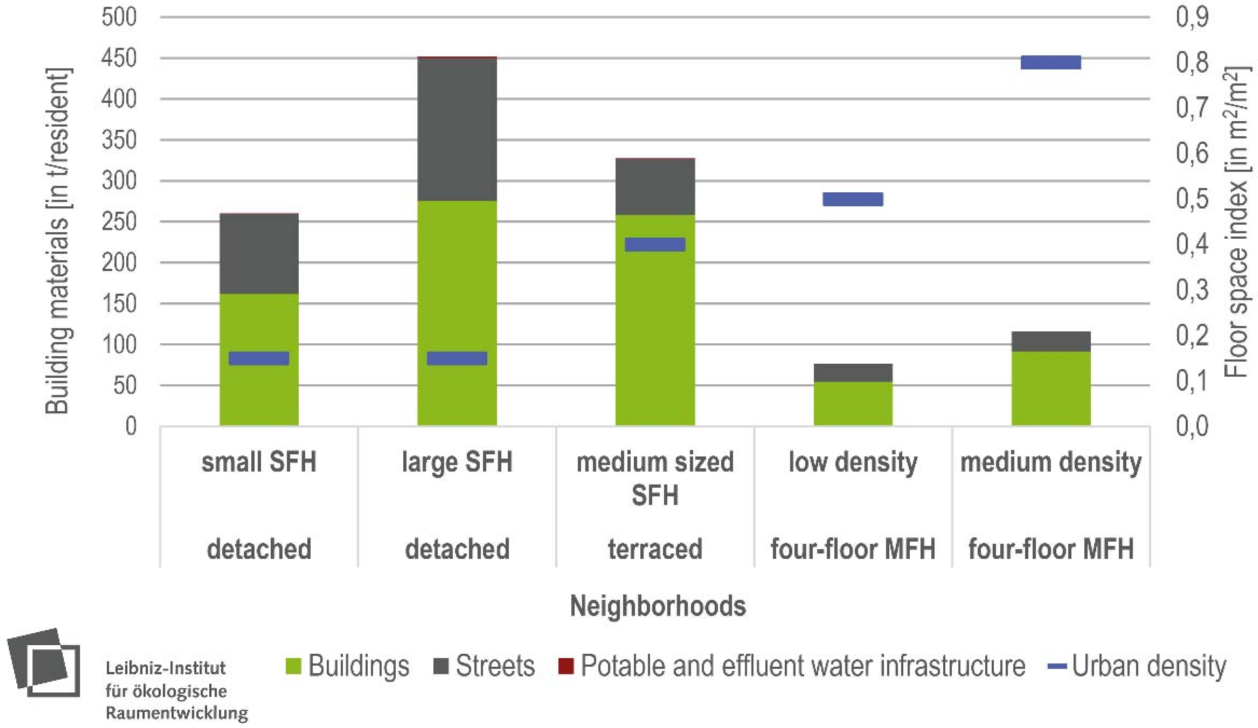

Fig. 2: Specific material input and floor space index for different SFH and MFH neighbourhoods

Having these particularities in mind, it becomes clear, that SFH neighbourhoods in terms of resource efficiency react more sensitive to changes in vacancy rates, than MFH districts. If we assume an average household size, the vacancy induced increase of per capita material intensity ("material rucksack") for the remaining residents – despite the lower vacancy rate for MFH and SFH as given above – tends to be similar or even higher in the SFH neighborhoods (Fig. 3)

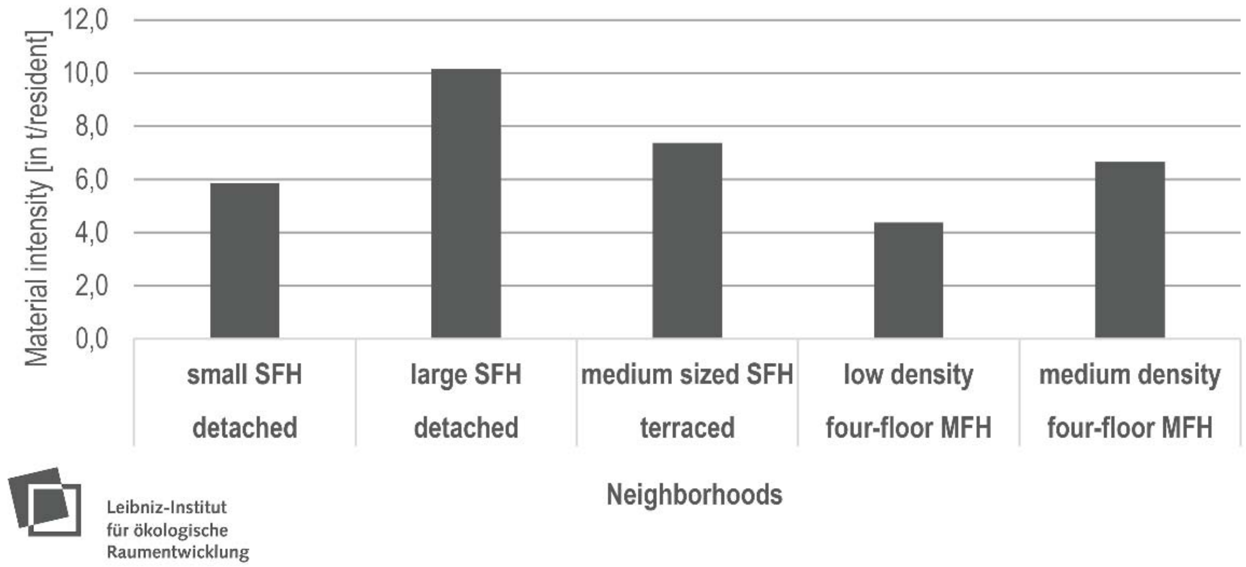

Fig. 3: Calculatory vacancy induced additional material rucksack per resident for different neighborhood types.

In other words: If we assume a synthetic neighborhood with 96 SFH equally mixed along the three types above, the resources “wasted” by 2,2% vacancy in these buildings in absolute figures clearly exceed the amount of unused resources induced by the 5,4% vacancy in a synthetic neighborhood with 96 flats in a 50/50 mix of the calculated MFH types (Fig. 4).

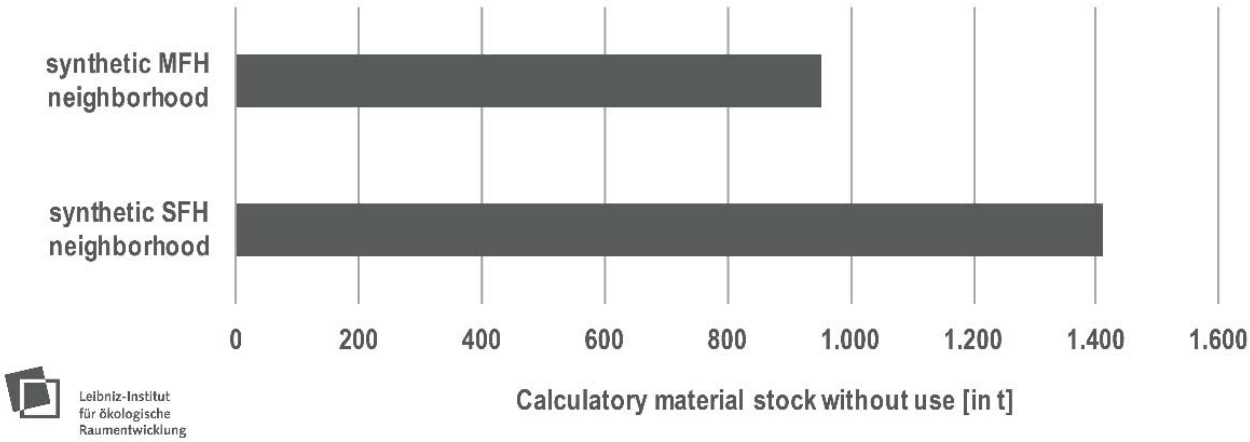

Fig. 4: Calculatory total vacancy induced material stock without use (“wasted resources”) compared for two synthetic neighborhoods (SFH and MFH).

4. Discussion

Trying to summarize the quite different impressions from the literature we can follow the authors of “Detached Houses – the Future” [45] for the situation in Switzerland where they highlight the typological diversity of suburban SFH neighborhoods and the need of tailor-made approaches when trying to develop these settlements in a more sustainable manner.

On the one hand the suburban SFH lifestyle still seems to be attractive for large groups of users. In particular metropolitan regions to a large extent seem to face business as usual – including extremely high prices for inner city housing that push less competitive households to the suburbs. On the other hand we find considerable indications for challenging developments. For example, beside the typical homogenous detached SFH settlements of the 1950s to 1970s also older inner city historic centers with small single family houses in smaller cities confront communities with development problems for example in terms of extensive vacancy [30].

With respect to sustainable development issues and resource efficiency in particular, the initial material stock estimates clearly indicate that with dropping demand and increasing vacancy, the efficiency of low-density SFH neighborhoods reacts highly sensitive in the negative sense, resulting in a waste of resources and land. In addition, the technical infrastructure services must be made available to an ever smaller group of consumers leading to higher costs for the remaining citizens. Furthermore, vacant buildings in an SFH neighborhood are much more dominant with respect to public appearance and character of the neighborhood than vacant single flats in a multi-family housing district. Growing vacancy rates in SFH neighborhoods can thus lead to a general down-trading of the whole district which ads a social and economic challenge to the environmental issue.

5. Conclusion

The first results of explorative research underline the relevance of changes in the development of SFH stocks for sustainable development at least in terms of resources and costs. Based on this status quo analysis it is now necessary to go deeper into regional differences and to generate reliable projections of future development scenarios as a basis for targeted and tailor-made approaches. At least locally SFH neighborhoods may form the redevelopment districts of the future.

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Solar collectors in a prefabricated housing estate: lessons learnt after four years of operation

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Summary

In the practice of Polish multifamily housing stock, environmentally friendly systems are rarely used. The paper investigates into the reasons of reluctance of facility managers and their clients in investing in what is expected to be, in the long term, beneficial for the nature and for the purse of users. A case study – a solar collector project in a housing cooperative – presents particular technical solutions adopted in 30-years-old precast panel blocks, and effects of the project in terms of financial benefits and user satisfaction.

Keywords: Solar collectors, hot water, system performance, user satisfaction.

1. Introduction

In the times of rapid technological development of technology related with renewable energy sources, and growing environmental consciousness of the public, investment to enhance energy performance of the existing housing stock seems obvious. However, the practice of Polish multifamily housing is not reach in examples of introducing modern environmentally-friendly systems to the existing (so most numerous) assets. So far, most effort was devoted to insulating the building envelopes and refurbishing heating systems with minor changes to their design. One of the bolder thermal renovation projects, involving solar hot water heating system applications to a multifamily housing complex, is the object of this case study.

In one of the housing estates in Zamość, a city located in south-eastern Poland, the management decided to install solar panels on the flat roofs of prefabricated housing blocks erected in nineteen-seventies and replace the existing hot water system with a solar one with auxilary heat provided by the local heating plant, equipped with individual heat meters. The costs of hot water preparation were significantly reduced (on average by 35%). The benefits of the project, apart from reducing the energy users expenditures, include providing a possibility to monitor hot water consumption in detail. The project resulted also in slight reduction of hot water consumption.

2. Methodology

The case study [1] was to provide insight into economic efficiency of investing in renewable energy systems applied to the existing prefabricated housing stock and to learn about attitudes of direct users of such systems. In Poland, such projects are extremely rare and the estate was one of a few examples of installing solar collectors on a larger scale.

The methods of the case study data collection were: analysis of documents provided by the housing estate managers (feasibility study, designs, building maintenance records etc.), direct observation, interviews with the housing estate managers, and a user opinion survey conducted in 2015.

The aim of the user opinion survey was to assess their satisfaction on improvements reached so far, and estimate their environmental consciousness and willingness to get involved in further measures for improving their living conditions. The method was a direct interview based on a questionnaire with a variety of closed- and open-ended questions [2]. The questionnaire was used before to collect input from other prefabricated housing estates, so its form had been verified in practice [3], and survey results could be compared with data from other locations.

3. Results

3.1 Project background

The object of the case study is a complex of prefabricated housing blocks in a housing estate of the Jan Zamoyski Housing Cooperative in Zamość. The flats in these assets are of mixed status: most of them are property of private owners, however, some users have limited property rights, and some are tenants. The estate stays under one management. However, mixed ownership implies that any decisions to modernise the existing stock must be consulted with the inhabitants and win their approval, and even a few people who oppose to new investment can block such initiatives.

In the past, the estate relied on hot water from the district grid, and the system was based on heat exchangers serving the whole quarters of the estate. Hot water prices used to be established uniformely for the estate as follows: the amount of heat used to maintain required temperature in the estate’s network was divided by the total volume of consumed hot water, and the amount payable for households was based on consumed quantity.

3.2 Description of new systems

Continuous growth of energy prices together with external funding opportunities was the reason why the cooperative management decided to invest in renewable heat sources. The project started in 2007 with three buildings being equipped with a solar collector system to heat hot water. The project was continued in 2010 with further 21 buildings. The estate, connected to the district heating distribution network, was equipped with a new local network with dual function heat exchangers (central heating/hot water systems) in each building that serve the new collector systems [4]. From the moment of installing the new systems, the hot water price is established individually for each building. The heat is paid in monthly advances, and accounts are settled quarterly on the basis of actual consumption of hot water. Meters are located in the flats, but the readings can be taken remotely from the staircase area. Figure 1 presents the battery of collectors on the roof of one of the buildings, and figure 2 and 3 – the distribution of the collectors on two levels of the roof. As half of the buildings were high raised, there was limited roof space for installing collectorsComplex geometry of the buildings' plan shape prevented using sun facing walls as support for collectors.

Fig. 1. Collectors on the roof of a high rised building (photo: A. Ostanska)

Fig. 2. Collectors on the roofs of high rised buildings arranged in two levels - making the most of limited roof area (photo: A. Ostanska)

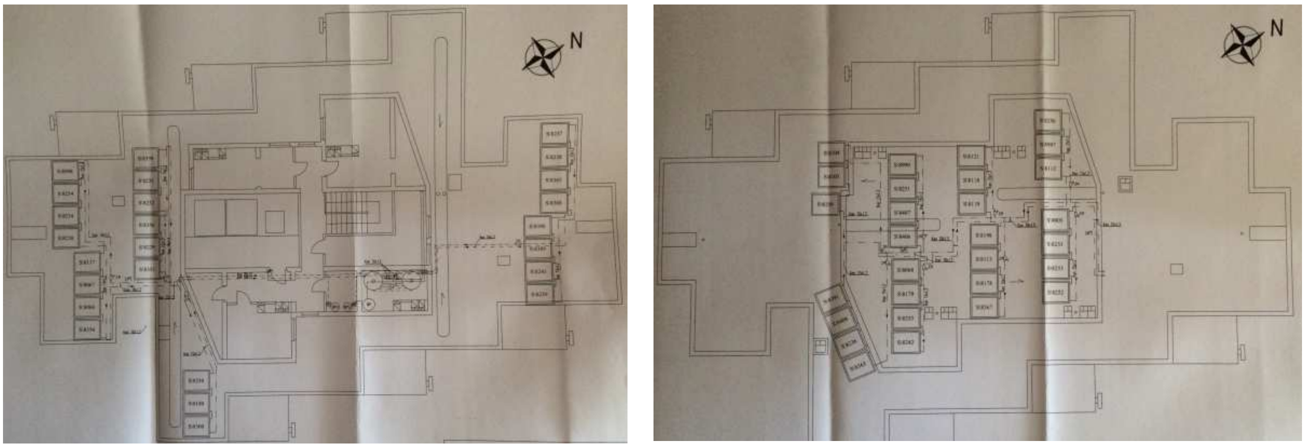

Fig 3. Concerns of orientation to the sun and complex plan shape affects distribution of panels. Source: the design by L. Gębski, Skorut Import Eksport Sp. Z o.o., 2010, with permission.

A typical one-building system is equipped with two separate circulation systems, one serving 29, the other 25 panels. The utility room located in the attic, formerly an open-access drying room (as a standard, the buildings of nineteen-seventies were equipped with this type of utility areas) houses pumps, a valve block and single coil hot water tanks of total capacity of 200m^3.

The transfer medium in the solar collector – tank coils circulation is a water solution of polypropylene glycol with additives. The pressure is provided by circulation pumps. The system is protected against excess pressure by a safety valve installed behind the pump and a membrane expansion vessel. The heat from the solar system is naturally not enough to provide enough – auxilary heat is provided by the local heating plant. Figure 4 presents a diagram of the heat exchange system.

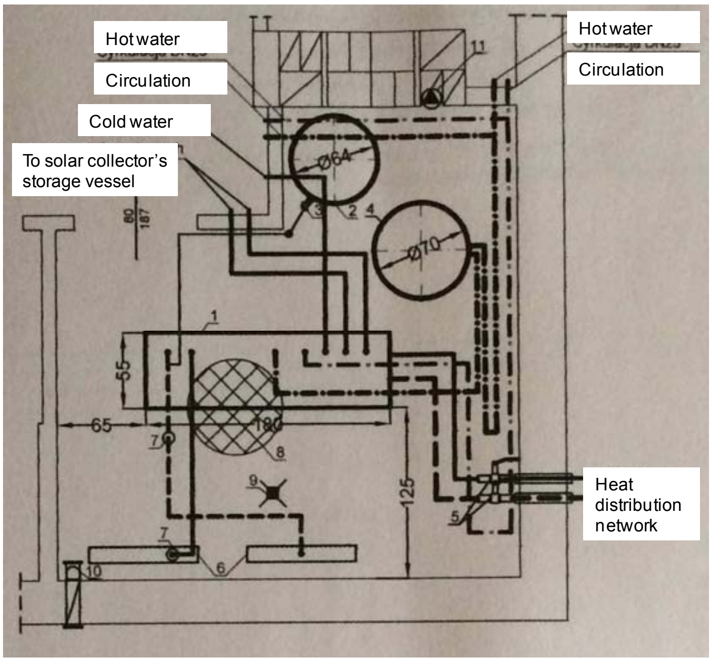

Fig. 4. Diagram of the heat exchange system. 1 – compact heat transfer station (heating and hot water, 290 kW), 2 – membrane expansion vessel for central heating, 3 – connector, 4 – hot water tank (domestic hot water), 5 – stop valve, 6 – valve block, 7 – automatic vent, 8 – cooling well, 9 – floor drain, 10 – air inlet, exhaust fan. Source: the design by L. Gębski, Skorut Import Eksport Sp. Z o.o., 2010, with permission.

3.3 Funding

The project was funded mainly from external sources, mostly grants: 50% came from National Fund for Environmental Protection and Water Management, 40% from EKOFUNDUSZ foundation, and only 10% from modernization funds of particular properties. Modernization of the estate's local distribution network was funded by a PLN 1 Million grant from SIDA (Swedish International Development Cooperation Agency).

3.4 Scale of savings

The sample is composed of ten housing blocks from the above mentioned complex, where the new system was installed in 2010. Records on hot water consumption and water heating cost indicate that the presence of the new system seriously affected running costs in four consecutive years of operation. The results, presented as percentage of 2010 figures of, respectively, the invoiced sums payable to the heat plant and water consumption, are presented in Figure 5. They indicate a slight drop in hot water consumption and considerable savings on hot water bills. Bearing in mind that the users practically did not pay for installing new system (90% grant funding), the household budgets were noticeably relieved.

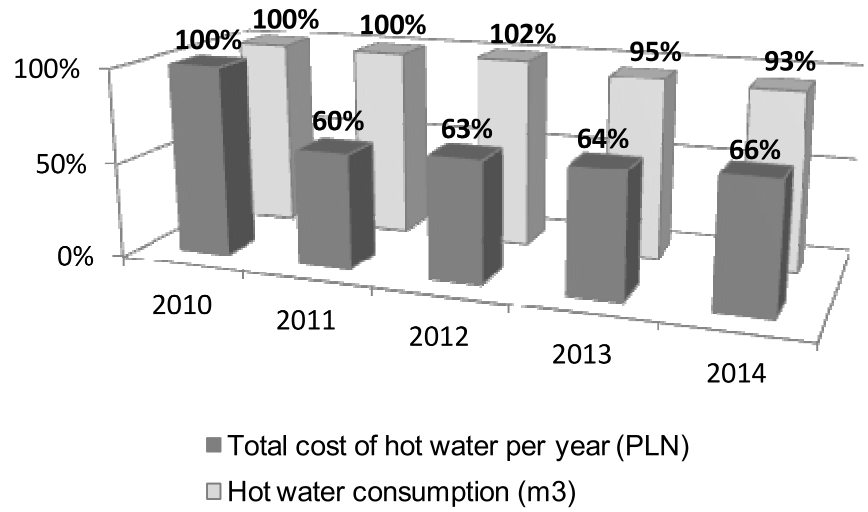

Fig. 5. Hot water consumption and hot water cost in consecutive years after project completion compared with 2010 levels.

3.5 User opinion survey

The opinion surveywas conducted in May 2015. Selected results of the survey are presented in Figures 6 and 7. The questions concerned, among others, overall satisfaction with living conditions and ideas for further enhancement of the buildings and investment with environmentally friendly solutions. For instance, many inhabitants would like to improve water management by using rainwater and gray water. They would welcome equipping the central heating system with more precise meters and individual control systems.

The aesthetics of the neighbourhood is generally considered sufficient: half of the interviewees are happy with it. The users would not oppose further changes to the building's fabric such as installing solar heat recovering facades and reshaping the layouts of flats. Lifts serving ground level would be welcome (all buildings are equipped with lifts, but there is one flight of stairs between the entrance and the first lift stop). Erection of vestibules and cladding balconies ale also considered a good idea to reduce heat loss.

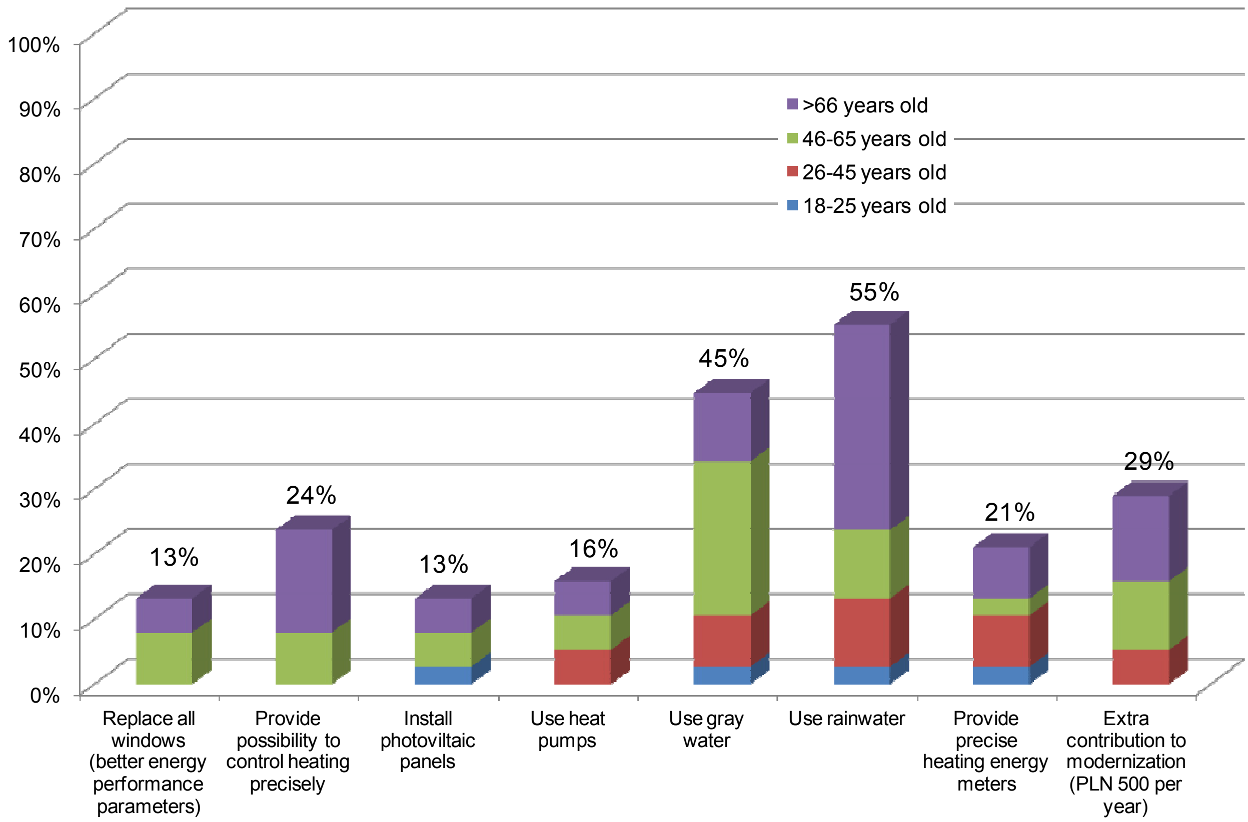

Fig. 6. User attitudes to other ideas for environmentally-friendly solutions

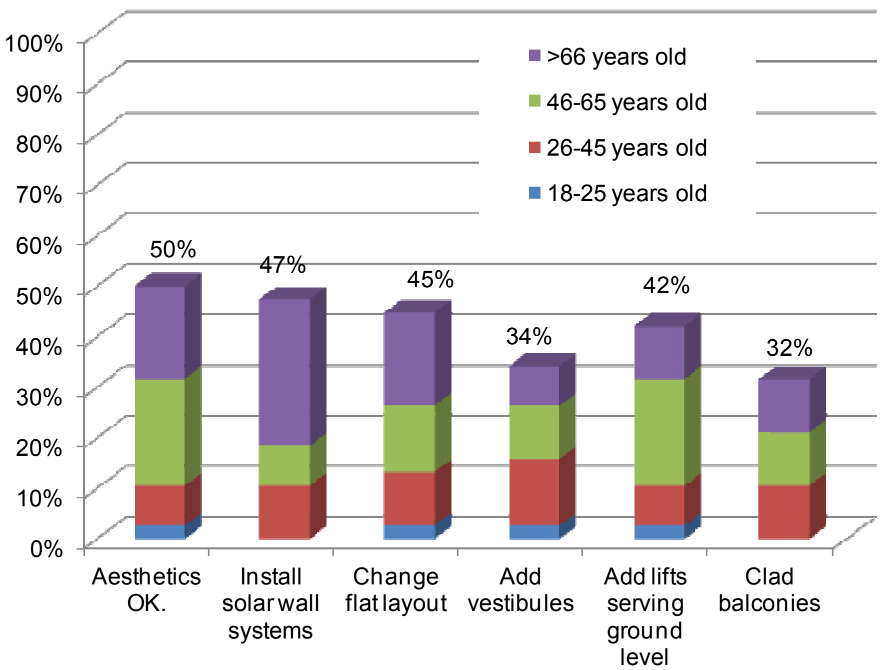

Fig. 7. User satisfaction andattitude to other ideas for building's improvement

4. Discussion

The presented project might be considered nothing special if compared with top European housing stock modernisations, and even the design of the hot water system may be not state-of-the-art. However, in the Polish practice, it is an example of out-of-the-box thinking of the cooperative estate management: observing what is being done in similar panel house estates, one must conclude that modernisation projects rarely go beyond covering building envelopes with brightly painted ETICS covers, changing heat exchangers and replacing ancient hot water grid pipes with new, better insulated ones.

Solar energy becomes popular, but mostly in private detached houses and new build blocks, but examples of a thorough redesign of heating systems in the existing housing stock, applied in more than one building at once, are still extremely rare. The considered project scale is not impressive (2513 m^2 of collector area sufficient to heat water, but not enough to contribute to central heating – limitations due to available roof area of mostly tall buildings in the estate) – compared e.g. with a similar project in Lodz. The Lodz project in Radogoszcz Zachod Estate [5], claimed to be one of the largest solar collector projects for housing, and completed in 2009-2010, can boast nearly 7400 m^2 of collector area serving a 57-buildings estate of uniform 5-storey blocks, with favourable rectangular plan shapes, to provide heat for a combined system of hot water preparation and central heating. Nevertheless, this project is a step forward, indicating that such ventures are technically and financially viable. The potential for using solar energy in prefab housing estates is hudge, and hopefully it is going to be exploited: there are thousands of square meters of flat roofs and south-facing, unshaded facades of structurally sound buildings in sparsely developed estates that just cry for being used to produce energy. Moreover, Poland becomes a leader in production of solar systems, and various forms of public support raised consumer interest in installing them.

Immediate reduction of hot water cost in effect of the solar collector project was considerable (about 35% in the 4-years perspective compared with the basic year of 2010). However, such savings are due to extremely convenient form of funding the project (public grants). It is enough to say that the estimated simple payback of the project is as short as 3 years. If the cooperative used only its own funds, it would grow to 35 years – beyond service life of the systems, making the scheme economically unjustified [6].

The opinion survey among inhabitants of the estate provided interesting results. Compared to findings of similar surveys conducted in other locations [7, 8], where no renewable energy sources were introduced (and, in general, less intervention to the internal fabric of the buildings was made), the willingness to invest in other kinds of environmentally friendly systems seems lower. The reason may be that, with this solar collector project, the people think they have reached a satisfactory level of benefits.

5. Conclusion

As supported by the evidence from the case study, investment in modernizing hor water system and introducing solar collectors proved profitable – from the point of end user. However, the project was possible only due to public grants. In Poland there are no examples of applying renewable energy sources to the existing multifamily housing stock without public support.

6. Acknowledgements

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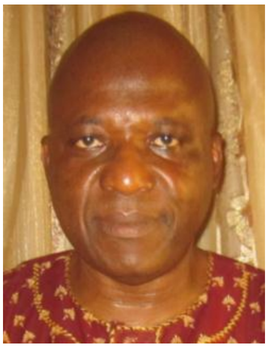
Stakeholders Awareness of Green Building and Sustainable Development Issues in Abuja, Nigeria

Full Paper



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Summary

The built-environment is a major consumer of non-renewable resources, producer of substantial waste, and a formidable polluter of air and water. Due to the limited reserves of our natural resources, the world will be faced with a situation of increased prices as the reserves are depleted while our natural environment is completely destroyed. Building sector in Nigeria consumes 60% of the total energy utilization in the country and the resources are not efficiently utilized. The goal of the study was to examine stakeholders' awareness regarding sustainable development issues, respective policies and constraints limiting their involvement in sustainable development. The sample consisted of 80 respondents randomly selected building owners, investors, developers, and others in Abuja, Nigeria. Descriptive statistics was used to analyze research questions 2 - 5. Findings revealed that majority of those surveyed are aware and highly involved in sustainable development efforts. Unsuccessful governmental implementation of environmental laws and government policies were also revealed. Inferences were made to improve awareness education through creation of guideline for improving awareness, advocacy and enlightenment programmes and empowering regulatory agencies to enforce and strengthen existing regulations.

Keywords: Awareness, Constraints, Green building, Sustainable development, Stakeholders.

Introduction

There is increased degradation of the built environment resulting from population increase, industrialization, migration and other human activities such as forest burning, operation of power plants, development in

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transportation systems, factories, and commerce. These human activities, because of their dependence on increased usage of fossil fuel, have caused large emission of Green House Gas (GHG) emissions such as carbon dioxide (CO_2), into our environment. Since the occurrence of energy crises of the early seventies, serious concerns had been expressed about the escalating cost of fossil fuels as well as its associated risk and the reality of environmental degradation [2]. Environmental pollution has also been blamed for the changes in climate.

The built-environment, comprising of buildings, civil and heavy engineering works, is a major consumer of non-renewable resources, produces substantial waste, and a contributor to land and air [3]. [4] also confirmed that the construction industry has tremendous effect on the society and the environment when compared to other sectors and industries in materials production and distribution as well as services sectors such as transportation, finance and the property market. Within the built environment profession, the principle of sustainable development is reduced to either sustainable construction or green building and this refers to any form of development such as building or communities that improves the human life and aspirations by balancing socio-economic development and environmental protection through the use of strategies, techniques, materials, and practices that are clean, resource efficient, and less pollution producing from the point of extraction of raw materials to the demolition and disposal of the built products [5]; [6]; [7]; [8]. Most sustainable development or green building practices fall into these five basic categories: 1.) energy saving, 2.) land saving, 3.) storm water runoff-reducing, 4.) material conservation and 5.) pollution reduction [9]; [10].

Despite the remarkable efforts made in the developed countries, sustainability issues and sustainable construction have not received sufficient attention and awareness in Nigeria [11]; [12]; [13]. In recent years, research shows that the awareness level in the construction industry is still very low and ineffective, and buildings are still being erected without taking the climatic consequences into account [14].

Nigeria as a country depends mostly on crude oil and electricity for its energy fulfillment. Typical methods for constructing new single-family homes, multi-family homes and commercial buildings are either not energy efficient or too costly for an average buyer after adding on the necessary components to make them energy efficient [15]. The country is faced with reality of environmental degradation, escalating cost of energy, erratic supply and distribution of electricity, and the need to develop a sustainable and efficient energy system. These emissions can primarily be traced back to, in addition to emissions from embodied materials. The current Nigeria's construction standards are not energy efficient because significant amounts of energy is utilized for cooling the buildings, cooking, cooling, heating, and lighting systems and appliances which results in increased greenhouse gas emissions nationwide. According to a survey in Nigeria, 60% of the total energy utilization is consumed by the building sector [1].

The goal of the study was to examine stakeholders' awareness regarding sustainable development issues, respective policies and constraints limiting their involvement in sustainable development. There were five major research questions for the study. The specific research questions were as follows: 1.) What is the current state of the art practice in the field of awareness for sustainable development around the world? 2.) What is the level of stakeholders' awareness regarding sustainability development issues in Abuja, Nigeria? 3.) How important, feasible, affordable and sustainable is green development in Nigeria? 4.) What are the constraints limiting participation in sustainability practice in Nigeria? and 5.) What are the cultural specifics of Nigeria that will allow transferring the results to other countries and areas of the world?

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2. Methodology

There were many steps involved in the design of the research. The procedure involved design of the survey instruments, validating the survey instruments, identifying the population for the study, selection of the samples, conducting pilot survey, conducting the survey, analysis of the collected data, and writing and disseminating the report.

The study population consisted of stakeholders. The stake-holders include owners, investors, developers, architects, engineers and facility managers in Abuja, Nigeria. The study utilized a simple questionnaire approach in which a total number of 80 questionnaires were distributed to various stakeholders in Abuja, Nigeria and 75 questionnaires were successfully retrieved and analyzed using SPSS version 21 and descriptive statistics such as frequencies and percentages. The sample size was calculated using a simplified formula proportion as illustrated by [16] as follows:

$$n = \frac{N}{1 + N(e)^2} \qquad (1)$$

Where; n = Sample size,
N = Population size in the sample unit,
e = Level of precision which is + 5% (0.05), at 95% confidence level.

In the study, a five degree Likert-type scale was adopted and arbitrary values of 1-5 were assigned to each of the degree of agreement, awareness, involvement, or participation, respectively. Disagree, somewhat agree, agree, strongly agree and very strongly agree responses were used depending on whether the particular response were considered to be acceptable or unacceptable based on the form of statement.

3. Results

Table 1 illustrates summary of the fieldwork response rate. As shown, out of the 80 respondents that received the questionnaire, only 75 (93.75%) actually returned completed questionnaire and five questionnaires were discarded for incomplete responses. As a result, only 75 questionnaires were considered for data analysis.

Table 1: Field Work Response Rate

Description	Numbers	Percentage
Total target population (stakeholders)	80	100
Undelivered survey (questionnaire)	5	6.25
Delivered questionnaire (stakeholders)	75	93.75

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Table 2 illustrates the respondent's age groups. As shown, all the respondents were over 35 years of age and 31 (41.3%) of the respondents were above 40 year of age.

Table 2: Respondent's Age

	Frequency	Percent
26-30	7	9.3
31-35	17	22.7
36-40	20	26.7
40 above	31	41.3
Total	75	100.0

Source: field survey, 2014.

Table 3 shows respondent's profession. As shown, 21 (28%) of the respondents were architects, 3 (4.0%) respondents were property owners, and only one respondent works outside the built environment profession.

Table 3: Respondent's Profession

	Frequency	Percent
Client	3	4.0
Architect	21	28.0
Builder	12	16.0
Q/surveyor	10	13.3
C/ M and E Engineer	18	24.0
Planner/Surveyor	10	13.3
Others	1	1.3
Total	75	100.0

Source: field survey, 2014.

Table 4 illustrates the respondent's level of awareness of sustainable development (green construction). The respondents were asked whether they have heard about the concept of sustainable development or green construction. As shown, 41 of the 75 respondents (54.7%) indicated that they are very aware of the concept, and only one (1) respondent indicated that he or she is not aware of the sustainability concept. The respondents were also asked whether they are aware that professionals in other fields are conversant about sustainable development issues in Nigeria. As shown, 29 respondents indicated that they are aware, and 9 respondents claimed that they are very much conversant about sustainable development issues in Nigeria. The respondents were further asked whether they are aware of the existence of any sustainable development (green building) projects in Nigeria. As shown, 54 of the 74 respondents claimed that they are either aware or very aware that sustainable development projects exist in Nigeria.

Table 4: Respondent's awareness of sustainable development (green construction)

Frequency (Percentage)	Not Aware	Strongly Aware	Aware Aware	Very much	Extremely Aware
1. As a professional, have you heard about the concept of sustainable development?	1 (1.3%)	3 (4.0%)	11(14.7)	41 (54.7%)	19 (25.3%)
2. Are you aware whether other built environment professionals in Nigeria apart from those in your field are conversant about sustainable development?	0	2 (2.7%)	29 (38.7%)	35 (46.7%)	9 (12.0%)
3.Presently, are you aware of the existence of any sustainable development (green building) project in Nigeria?	12 (16.0%)	6 (8.0%)	27 (36.0%)	27 (36.0%)	3 (4.0%)

N = 75

Table 5: Respondent's involvement with other professionals in creating awareness

Frequency (Percentage)	Not Involved	Somewhat Involved	Involved	Very Involved	Extensively Involved
1. Have you been involved with other professionals in creating awareness about sustainable design and construction?	0	2 (2.7%)	17 (22.7%)	45 (60.0%)	11 (14.7%)
2. Have you been involved with in any sustainable development projects before?	6 (8.0%)	17 (22.7%)	28 (37.3%)	19 (25.3%)	5 (6.7%)
3. What was your level of involvement in sustainable development projects?	7 (8.8%)	18 (22.5%)	30 (37.5%)	20 (25.0%)	5 (6.2%)

N = 75

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Table 5 illustrates the respondents' involvement with other professionals in creating awareness about sustainable development. As shown, 2 respondents are somewhat involved, 17 involved, and none of the respondents claimed to have not been involved with other professionals in creating awareness about sustainable development.

Table 6: Respondent's perception regarding the importance of sustainable development to Nigeria.

Frequency (Percentage)	Not Important	Somewhat Important	Important	Very Important	Extremely Important
1. How important is sustainable design and construction to your profession?	0	2 (2.7%)	16 (21.3%)	34 (45.3%)	23 (30.7%)
2. How important is sustainable development to the Nigerian construction industry?	0	1 (1.3%)	16 (21.3%	41 (54.7%)	17 (22.7%)
3. How important is sustainable design and construction to Nigerian economy?	0	3 (4.0%)	12 (16.0%)	35 (46.7%)	25 (33.3%)

N = 75

Table 7: Green Building Rating

Rating Systems	Frequency	Percent
LEED, USA	41	54.67%
CASBEE, Japan	6	8.00%
Green Globe, Canada	8	10.67%
Green Star, Australia, etc	12	16.00%
HQE, France	8	10.67%
Total	75	100.0

Table 6 illustrates the respondents' perception regarding the importance of sustainable development. As

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shown, the majority of the respondents perceived sustainable development as important 16 (21.3%), very important 34 (45.3%), or extremely important 23 (30.7%) to their profession, the construction industry, and the Nigerian economy. None of the respondents perceived sustainable development as not important.

Table 7 illustrates the respondents' familiarity with green building rating scales and whether they would recommend it to Nigeria. As shown, majority of the respondents (41 out of 75) indicated they are familiar with LEED rating scale and would recommend this for Nigeria.

Table 8: Respondent's believe regarding feasibility, affordability and sustainability of Green development

	Frequency (Percentage)				
	Does not Believe	Somewhat Believe	Believe	Strongly Believe	Very much Believe
1. Do you believe that sustainable development is feasible in Nigeria?	0	3 (4.0%)	11 (14.7%)	49 (65.3%)	12 (16.0%)
2. Do you believe that Nigerians can afford sustainable buildings?	0	0	11 (14.7%)	43 (57.3%)	21 (28.0%)
3. Do you believe that you can encourage Nigerians to adopt green construction instead of conventional construction?	6(8.0%)	3 (4.0%)	24 (32.0%)	30 (40.0%)	12 (16.0%)
4. Do you believe that sustainable development is practicable in Nigeria, considering the present economic level and the shortage of decent and energy efficient homes?	3 (4.0%)	3 (4.0%)	14 (18.7%)	40 (53.3%)	15 (20.0%)
5. Do you believe that the construction of green building will improve the standard of living in the nation?	0	0	15 (20.0%)	40 (53.3%)	20 (26.7%)
6. Do you believe that it is important to give considerable attention to sustainable development effort at this point in our nation's development?	0	0	9 (12.0%)	39 (52.0%)	27 (36.0%)
7. Do you believe that there is an urgent need for sustainable development in Nigeria?	0	0	13 (17.3%)	36 (48.0%)	26 (34.7%)
8.Do you believe that sustainable design and construction can help provide a healthier environment for living?	0	1 (1.3%)	7 (9.3%)	29 (38.7%)	38 (50.7%)

N = 75

9

Table 8 illustrates the respondents' believe that design and construction of sustainable building is feasible in Nigeria. As shown, majority of the respondents believe that sustainable development feasible, affordable, and will improve the standard of living in the nation. None of the respondents claimed that they do not believe that sustainable development is feasible in Nigeria.

Discussion

Discussion of Research Question Number One: Question one addresses the current state of the art practice in the field of awareness for sustainable development. Table 7 reveals the popular Green Building Rating Systems that are recognized worldwide. The literature revealed that there is no universally accepted rating system for sustainable development. Instead, each country adopted a system that are based on their cultural diversity, equity, justice, and participatory democracy, involving collaborative process between geographically and culturally diverse group of civil society organizations (CSOs) and researchers.

Discussion of Research Question Number Two: Question two addresses the level of stakeholder awareness regarding sustainable design and construction in Nigeria. Result shows that high level of awareness of green construction exists and the majority of the respondents also indicated that they are capable of advising Nigeria, to adopt green construction instead of conventional building. This is probably because they are aware that green construction is healthy, requires minimum maintenance, has little impact on the environment and they make use of natural resources. Casual observation revealed that the majority of the existing so called green buildings are not up to standard because they are neither constructed using acceptable rating systems nor with standard materials, and the contractors are not certified to construct green buildings.

Discussion of Research Question Number Three: Question three addresses the importance, affordability and feasibility of green development in Nigeria. Table 6 reveals respondent's perception regarding the importance of sustainable development to Nigeria, and Table 8 reveals the respondents believe regarding feasibility, affordability and sustainability of Green development in Nigeria. As shown in Table 6, majority of the respondents 34 (45.3%) believe that sustainable development is very important, and 23 (30.7%) believe they are extremely important. In addition, Table 8 also shows that majority of the respondents claimed that the adaptation of green development principles is both feasible and affordable. It is anticipated that this effort will add a considerable solution to Nigeria's energy challenges such as the challenge of connecting most rural areas to national grid for its energy use. Green construction is also considered essential in the practice of green architecture and environmental sustainability both in urban and rural societies in Nigeria. However, there are no guidelines for improving awareness, adaptation, and implementation of green building practices in Nigeria. This calls for a rethink among built environment professionals regarding the way we design, construct, and operate building, to match our current realities with anticipated future challenges. The current effort is focused on reducing the energy intensity of buildings through the use of insulating materials, low energy lighting and natural ventilation.

Discussion of Research Question Number Four: Question four addresses the constraints limiting participation in sustainability practice in Nigeria. The review of the literature revealed that even though there are environmental laws and regulations in the country such as the Federal Environmental Protection Agency Act of 1988 (FEPA Act), National Policy on the Environment (NPE) 1989 and Environmental Impact Assessment Act of 1992 (EIA Act). The approach of these regulatory organizations is the prevention of environmental damages, the regulation of potentially harmful activities and the punishment of willful harmful damage whenever this occurs. The environmental agencies also adopt the approach of engaging individuals and communities at risk of potential environmental damage in dialogue [17]. Other critical barriers identified in the literature include lack of government support and incentives, and lack of relevant building codes and standards.

Discussion of Research Question Number Five: Question Five addresses the cultural specifics of Nigeria that will allow transferring the results to other countries and areas of the world. The principle of building life cycle is universal and countries have different cultures that influence their behavior and choices. Transfer of the results should be limited to areas with similar culture.

Conclusion

The researchers concur with the respondents' claims that the provision of sustainable development is important to the Nigerian construction industry, that sustainable development will improve the standard of living, provide healthier environment for living, and should be encouraged in Nigeria. However, respondents claims that green housing is affordable by Nigerians and the practicability is unrealistic and over ambitious, considering the current state of housing conditions in the country and the government housing policy. On one hand, the Nigerian government has continued to insist on ensuring adequate housing for all as a primary housing policy objective in the face of compelling arguments on the limitations of the unregulated market in achieving such an egalitarian objective [19], [20]. On the other hand, the Nigerian government is currently implementing broad deregulation policies in foreign exchange and finance markets, trade and investment, and industrial development within the framework of economic structure adjustment and reforms, which seek to promote private sector-led housing provision. According to [21], this policy orientation tends to discourage the use of innovative direct supply-side and demand-side subsidies, to promote housing sector development. [22] warned that "the present move or tendency on relying wholly on market forces of demand and supply and leaving housing to private initiatives will not solve the problems of housing shortages and quality in the country" (p.132). Such observations raise concerns about the suitability of current housing policy orientation in dealing with Nigerian housing problems. Lack of finance for housing construction and home ownership, increase in prices of building materials, and lack of technical knowledge has further reduced housing affordability for most Nigerian.

The study did not establish whether the built environment professionals surveyed had any training or certification such as LEED or a University degree in sustainable development. It appears that there is a lack of institutional structure for promoting sustainability issues in the country and there are difficulties in understanding and incorporating the idea of green building innovation into building practices. However, it is overambitious to start taking of implementing a sustainable development standard when basic standards for conventional housing do not exist. At the moment, the country does not have a building code setting the minimum design standards for health, safety and welfare of occupant and the government is yet to pass a 2006 Building codes and standards into law.

Finally, the literature revealed the existence of several environmental laws and policies, and the fact that most Nigerian legislations crumble at the implementation stage. This is probably due to inconsistencies in government policies sometimes caused by change in regime and the limited understanding of the process of transferring the laudable provisions into effective tool for managing the environment.

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Strategic Urban Energy Planning - Vienna 2050

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Summary

In behalf of the Vienna Municipal Department 20 - Energy Planning a guideline including nine concrete operational steps and a computer-aided tool to support a scenario based decision making for strategic urban energy planning were developed. The guideline and the tool are designed to structure the planning process and to secure the achievement of ambitious sustainability targets for the housing sector. These targets are defined by the Vienna city authorities and include the reduction of energy consumption and of CO_{2eq}-emissions.

Keywords: strategic urban energy planning, housing sector, emission reduction, continuous output reduction

1. Introduction

Vienna is a rapidly growing city with an average annual influx of 14.000 people and an estimated yearly need for 8.000 additional flats to the existing stock of 880.000 units.[12][14] Simultaneous the Smart City Wien – framework strategy fixes strict reduction targets for CO_{2eq}-emissions and energy consumption for 2050.[5] Against this background, the municipal authorities decided to systematically coordinate the superordinate planning of energy provision and power supply with the overall design of city development areas in the early stage of conception. This task was named strategic urban energy planning and needed situation specific instruments. These instruments should empower all stakeholders to participate in the planning process and secure the sustainability of the development.

2. Methodology

The development of the guidelines and the computer-aided tool for the strategic urban energy planning starts in parallel with the preliminary phase of a cooperative planning procedure for the development area of Oberes Hausfeld with 3.500 flats projected. The municipal authorities establish an open exchange of information and support between the stakeholders involved in these two planning processes. Thus the theoretically elaborated instruments for the strategic urban energy planning considerably benefit in their development from the possibility to assess their practical suitability in the cooperative planning procedure. Within the process the essential concrete operational steps to generate an adequate depth of planning are identified. Moreover the state of complexity is determined that reasonably asks for support of a computer-aided tool for a scenario based decision making. The design of the tool makes a user-friendly application focusing practical solutions on a professional technical basis available.

3. Results

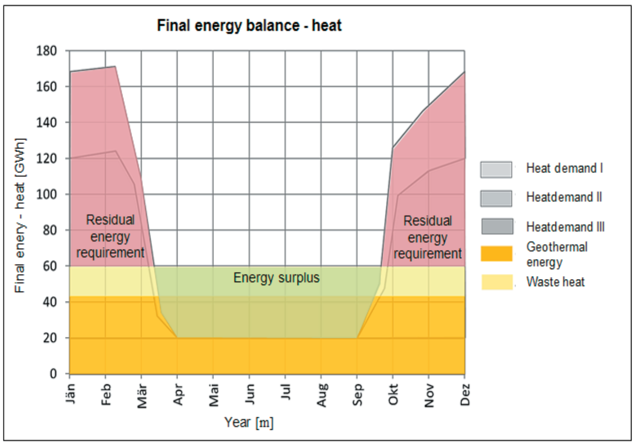
The objective of strategic urban energy planning is defined as formulating clear requirements for the area development to secure the achievement of the sustainability targets determined by the city authorities. The need of strategic urban energy planning as an integral task within the preliminary strategic planning phase of city development areas is confirmed.

3.1 Locating strategic urban energy planning within super ordinated development processes

To make the implementation of strategic urban energy planning into development processes easy the new element is introduced integrated into the scheme of guidelines of project controlling of the Austrian chamber of architects and consulting engineers most planners are familiar with. [1] There the strategic urban energy planning is ranged in the strategic preliminary planning phase with comparable other processes.

3.2 Nine operational steps towards a strategic urban energy planning

Nine concrete operational steps are identified to practically structure the process of strategic urban energy planning and generate an adequate depth of planning. These nine steps are; one - clarifying the energy demand to expect, two - analyzing the potential of environmental energy on-site, three - calculating the local energy coverage rate, four - covering the residual demand, five - developing energy supply scenarios, six - controlling of target achievement, seven - comparing life cycle cost, eight - taking a binding decision and finally nine - formulating requirements for the overall design of the development area.



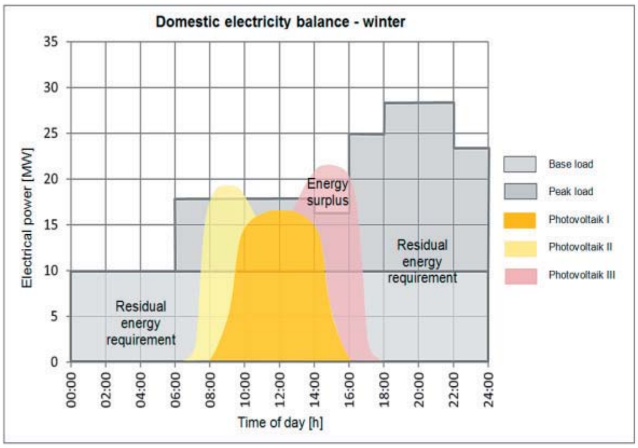


Fig. 1 and 2:
Exemplary balance sheets resultingoperational step three: calculationg the local energy coverage ra

3.3 Computer-aided tool for a scenario based decision making in strategic urban energy planning

Within step six, controlling of target achievement, where the energy supply scenarios elaborated in step five are compared, the state of complexity is determined that reasonably asks for support of a computer-aided tool for a scenario based decision making. As the Smart City Wien – framework strategy gives a scope of reducing the continuous output from 3.400 Watt per capita to 2.000 Watt per capita and of the CO_{2eq}-emissions from 3.1 tons per capita to 1.0 tons per capita within 2050, for the city as such, first the share of the housing sector of these reductions is figured out. [2][3][5] Following four fields of intervention– namely the average living area per capita [4][12][14], the building energy efficiency [6][7][13], the mix of energy sources [8][9][10][11][13] and the energy generation [15][16] are identified and a range of the reduction contribution in each field is determined. A computer-aided tool is designed to make the reduction effects for combinations of different scopes of measures in the intervention fields visible. Finally scenarios for 2020 and for 2050 are modeled to give benchmarks for specific development tasks. Now it can be stated if for instance reducing the average living area per capita by 5% from the current in combination with using an on-site low temperature heat resources leads to a fulfillment of the defined targets or if other or additional measures have to be taken.

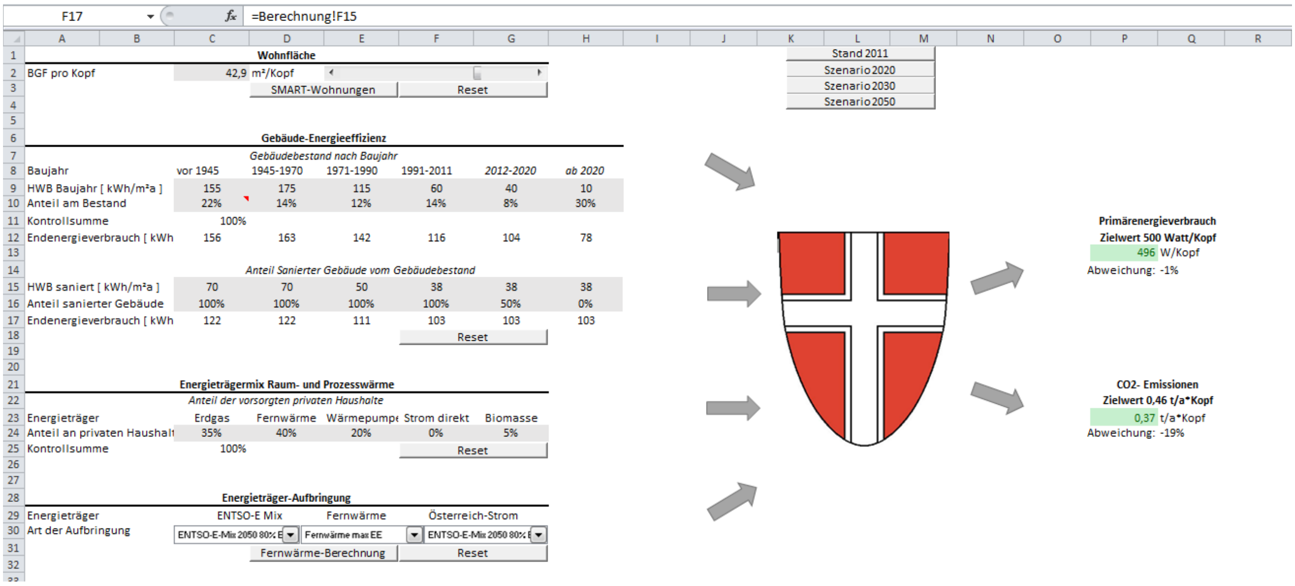


Fig. 3: User interface of the computer-aided tool for a scenario based decision making in strategic urban energy planning – result sheet

4. Discussion

The possibility to assess the practical suitability of the theoretically elaborated instruments for the strategic urban energy planning in an ongoing cooperative planning procedure opens up the rare opportunity of immediate critical reflection on the applied research done. In this context the establishment of strategic urban energy planning within super ordinated urban development processes is considered to be necessary to transform towards sustainability. The firmly location in the preliminary phase of strategic planning as explained is regarded as helpful and enhancing planning security for all stake holders. The nine operational steps towards a strategic urban energy planning provide a guideline to generate an adequate depth of planning. To the current experience the questions issued in the guideline seem to be essential. But still the guideline is open for adaption to special cases of planning, to various data situations and even to wider changes of the given scenario. The sequence of the operational steps is not seen as fixed except for generating causality. Working on the computer-aided tool for a scenario based decision making in strategic urban energy planning needs ongoing critical analyses. Especially designing future scenarios, uncertainties in various fields like energy supply and accessibility, population development or climate change occur, which may make the meaningfulness of the tool doubtful. Never the less in the building sector we are forced to work within a wide time horizon. Thus the tool can only provide a rational and adaptable basis for decision making combining data given from the actual point of view.

5. Conclusion

Supported by the computer-aided tool developed for a scenario based decision making in strategic urban energy planning, and by analyzing real cases of urban development planning, it is shown that by reasonable combining ambitious measures in the city development areas and in different fields of intervention the developing Viennese building stock as such could meet the requirements of the Smart City Wien – framework strategy for 2050. It is possible to establish a sustainable and to a high extent self-subsistent energy provision and power supply for the city.

6. Acknowledgements

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Strategies Analysis on Simulation Application of Sustainable Strategies Development in the Conceptual Design

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Summary

The paper is about strategies analysis on simulation application in the conceptual design stage, which serves as a guidance for architects confused with simulation. Based on a review of typical case analysis supported by simulation tools, a strategy framework is provided in a view of architects operation. The study exemplified the strategy through a practical project for a museum and shows how simulation can effectively contribute to the improvement of the sustainable design process in the two fields, CFD and natural light. Finally, the paper summarizes the role of the simulation and some potential drawbacks in the sustainable design process in order to combine simulation and design more effectively.

Keywords: Application Strategy, Sustainable Design, Simulation Application, Case Analysis, Conceptual Design

1. Introduction

1.1 Strategies of Simulation Application in Early Stage of Design

In terms of sustainable development, the conceptual form of architecture is determined by the environmental particularity [1], which means by the beginning of a project, architects need to find a proper conceptual form to handle the problems about various limits or conflicts of the site and local micro-climate. And BPS (Building Performance Simulation) has the potential to contribute to a sparkle of inspiration about the concept and the logic of an organized form in the complicated process, because of exceling at the quantification of the abstract problems and the visualization of the weakness in the conceptual form [2]. Hong et al. [3] conclude presciently that BPS acts not only the quantitative assessment tools for the design, but also makes it possible to reveal the interactions between sustainable concept, conceptual form and its performance level.

Above all, the drive towards sustainable design raises challenges for architects. [4] These, especially deeply in association with practical process, may stem from the desire to start a sustainable concept in a proper design logic, and the need to develop a design with proper association of BPS in the early stage. It is both related to the BPS application issues. And proper design tools may be constrained by the technology development in certain period, but working methods in a non-program-specific manner could adapt to the present and contribute to the further evolution of BPS tools, which could practically help architects in the design process. Thus, architects need to seek a different path of the cooperation between design and simulation in the start of a project.

2. Methodology

2.1 Case Analysis through BPS

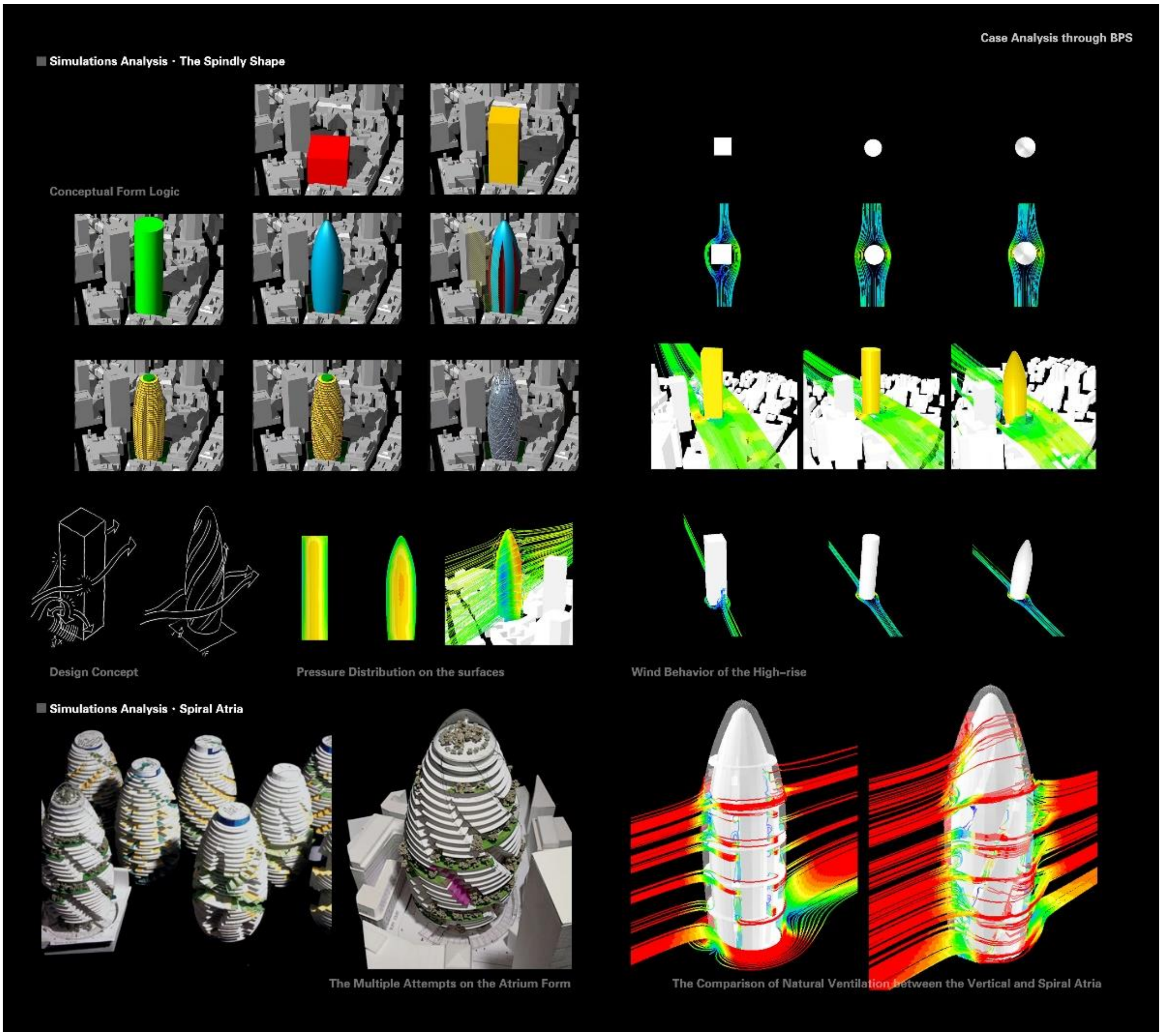

Fig. 1 Case analysis of the Swiss Tower

The research starts from the typical case analysis, which is an effective way to establish the framework of strategies. And BPS can provide the quantitative statistics to the rational judgment about the green architecture design logic, make it possible to represent the generation of architectural forms more exactly and clearly, and provide more tips of BPS applications in the design process in another way. J.A. Clarke and J.L.M. Hensen call the essential attribute of simulation as learning support. Cases are selected from a large number of typical green architecture practices in all over the world by various famous architects, such as Norman Foster, SOM, and so on, which are characterized by unique shape, reasonable design logic and building performance improvement strategies. And case analysis consists of four parts. The firt step is the objective statement of design characters which is about the unique shape, design strategies and climate considerations. The second is the detailed summary of archtects' design logic which includes design targets, method and process of organization. The third one is visual BPS experiments developed through the reasonable review and reconsideration about the design process. The last is systematic results analysis which describes the design reality, seek the hidden drawbacks, explore the potential improvement, and contributes to the rethinking of the process with BPS.

Take it as an example the Swiss Tower. A series of simulation experiments were taken to testify this design process (Figure 1). And just like the case analysis above, the accumulation of results can provide systematic strategies and critical reference of integrated design method with BPS application.

2.2 Strategy Framework

Based on systematic case analysis above, a strategy framework could be established below.

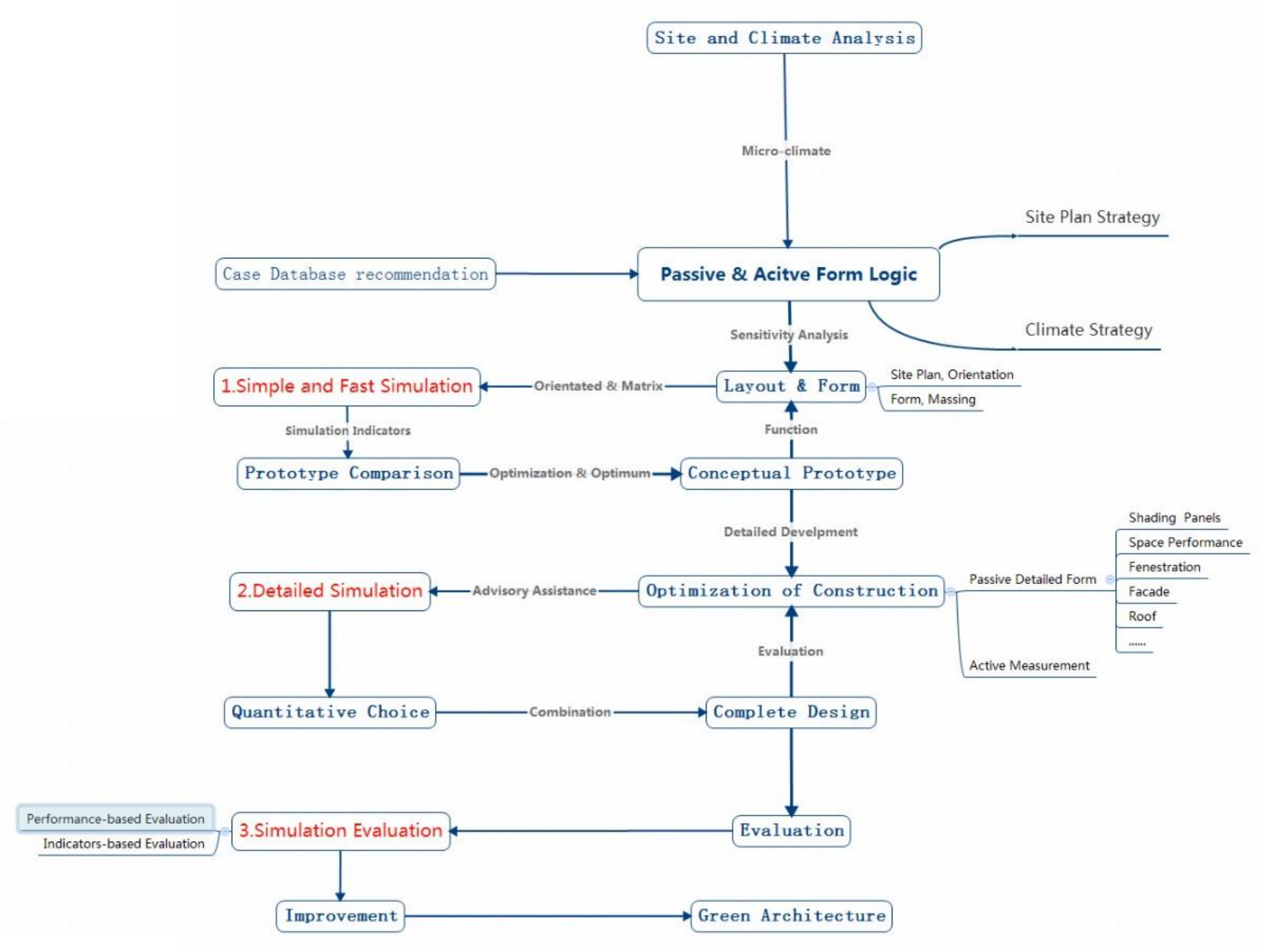

Fig. 2 Framework of design process

As the Figure 2 shows, the design process is divided into three phases based on the design contents, in which BPS could participate with different computational accuracy.

For the first step, it is the most significant phase of the whole design process which establishes the dominant direction and unique character of a design with the explicit sustainable design strategies and design logic. And the role of BPS is quite simple but effective. This stage consists of two parts. The first part is “Strategies-making” which stems from climate analysis of local features and micro-climate strategies, such as site limitations and cultural advantages. Moreover, the case database established by Case Analysis above, could provide various directions of design strategies, practical reference for form logic in the similar strategies and recommendations for BPS application in strategies-making. According to the design strategies and case database recommendation, the form logic of organization is created, including layout and form, which establishes the initial model. The next work is to testify the reasonability of this initial logic. In this process, all the boundary conditions is same except the distinction between different model attributes, which contributes to the comparisons of variables in form difference. This simple and fast simulation providing the dominated indicators’ comparisons, could simplify the complicated input, shorten calculation time span, reduce simulation erro and visualize the performance drawbacks on the model itself. Resultingly, it weakens the uncertainty and complexity of simulation in the conceptual stage, to leave enough space and time for architects in form thinking and logic organization. The comparisons could be developed in an orientated or matrix way. After comparisons, architects will find a proper optimized model as the conceptual prototype which meets the preliminary strategies and is developed into a high-performance form with the ensurance of BPS. Last but not the least, the form needs to be modified to meet the needs for functions and other architectural issues, which will be return to the same workflow above one more time to ensure the reasonability.

The second step is the “Optimization of Construction” based on the detailed development of conceptual prototype. It means that architects need to calibrate the model with more reliable techniques which include passive detailed form and active measurement. The passive detailed form could consist of shading panels design, public space with high performance, fenestration, facade, roof and so on, which could be more easily controlled by architects in a way of form creation and modification. Another part, active measurement determines the energy consumption and technology performance, which could stimulate the inspirations in construction. In this process, architects could work as a director with the advisory assistance from more perfessional field of some issues. Under the control of form logic and design strategies, more detaied simulations could be separatedly distributed into different perfessionals by architects. This detailed simulation should be more accurate with the practical boundary conditions and specific models, and be optimized on a quantitative results to ensure the real performance.

The last part is simulation evaluation in order to meet some criterions of performance-based evaluation or indicators-based evaluation. This part is more dependent on the specific values rather than the design itself, so the influences of architects is the least.

Table 1: Simulation and Architects’s Duty in Each Stage

Proccess	Design Process		Evaluation Proccess
Stages of Proccess	**Simple And Fast Simualtion**	**Detailed Simulation**	**Simulation Evaluation**
Computational Accuracy	simple and fast with the same and simplified boundary conditions except the distinction between different model	more accurate with the practical boundary conditions and specific models, and be optimized on a quantitative results to	absolutely accurate for the evaluation

	attributes	ensure the real performance	
Aim of Each Stage	concept/strategies-making	optimization of detailed construction	to meet some criterions of performance-based evaluation or indicators-based evaluation
Data Base	climate, micro-climate, local features, case database	conceptual prototype	detailed and systematic models
Architects' Focus	high-performance form logic for the strategies	passive detailed form and active measurement	/
Architectural Vocabulary	layout, conceptual form	specific and detailed form for passive and active desgin(roof, shading panels or sth. alse)	/
Evaluation Criterions	high-performance, cultural advantages, function needs	detailed and specific values in practical use	evaluation standards or regulations
Working Method	the orientated or matrix comparisons directed by architects	advisory assistance with architectural language	evaluation group
Architects' Duty	designer	director	/

We can see from the Table 1, the strategy framework of BPS application in conceptual design is fouced on the first phase and partly the second phase. It illustrates the role of archtects as well as the distinguished BPS application strategies in conceptual design. The framework aiming at practical workflow itself, is relatively practical because it is not limited to some BPS tools, but adapts to the gradual evolution of BPS development with the wide-open thought, and it is flexible to the various kinds of specific tools which serve as the stimulation of inspirations rather than the confusing constraint of design process. It can accommodate different skill levels of architects from the operation level. With it, architects can work explicitly, adhere to their design concept and use BPS tools reasonably, ranging from specific mathematical model to some integrated platform or parametric design tools, which just show the distinction on the practical operation level. It means that practitioners could easily pay more attention to the design itself rather than the confusing assessments.

Fig. 3 Two different schemes of a museum design

2.3 Case Experiment

This part will exemplify the strategy framework above through a practical project of a museum design. As the Figure3 shows, the project is developed by two different schemes whose conceptual design process, logic development and BPS application in the early stage is illustrated. This way helps to concentrate on the framework itself without the uncertain influence of single case so as to testify the framework and find out some potential drawbacks.

2.3.1 Design strategies

The site has a temperate seasonal climate with the tradition of outdoor activities in a good natural atmosphere. So the design strategy in the first phase is to protect the surroundings from the bad influence brought by the huge massing of a museum, especially in the terms of natural ventilation and outdoor activities.

2.3.2 Form logic

Based on that strategy, a maximum volume is shaped to leave enough space for the surrounding trees on the site, and the volume is also partly set below ground to protect the quiet garden against the noise from main stream of people and leave more space for the outdoor activities.

After that, the design logic is developed into two different directions which are both based on the natural ventilation strategy with BPS assistance. And the two prototype models are shaped into different forms based on the simple and fast simulation process.

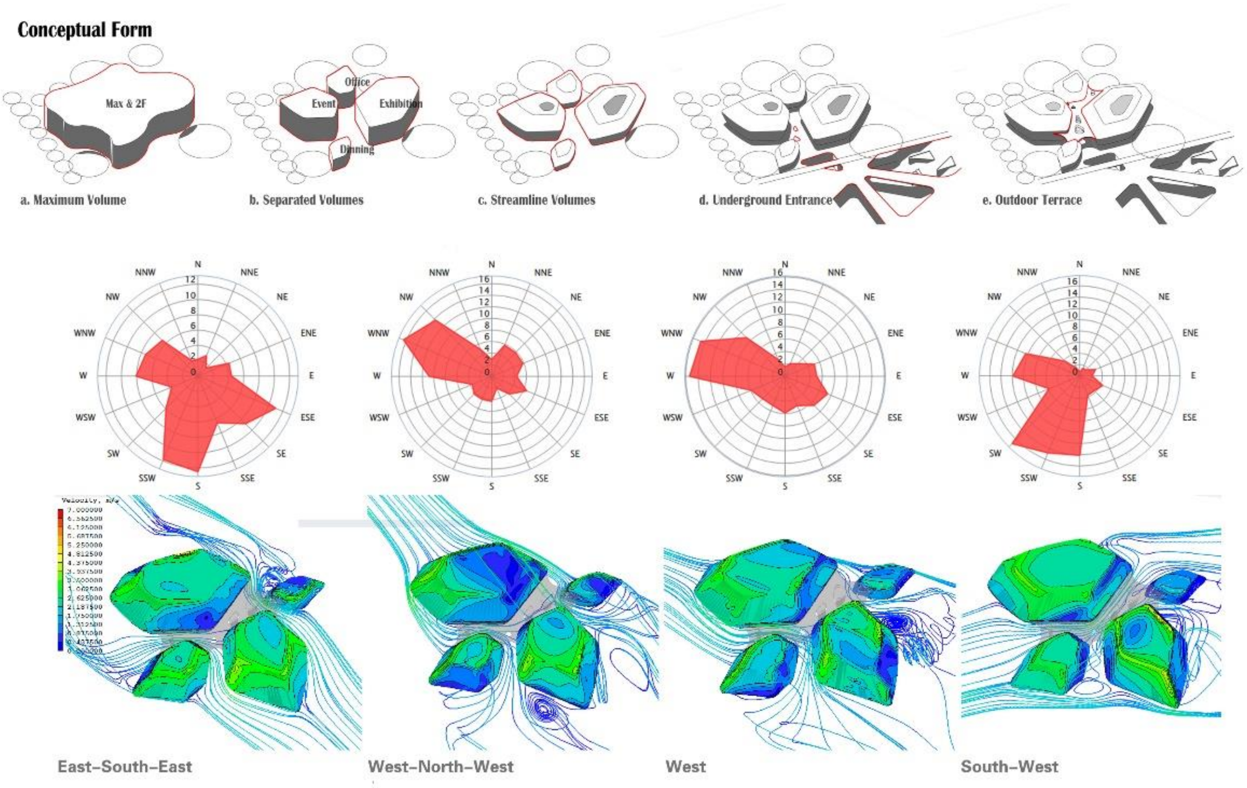

Fig. 4 Simulation of natural ventilation

Scheme 1

First, the whole volume is separated into four parts of different functions which could also vary in the way of lighting and natural ventilation. This way could create several new paths connecting the eastern pavement and natural garden on the other side. The vertical walls of these volumes are bended to leave more space on the ground and increase the ratio of facade for solar energy gain. From the simple and fast BPS, we can see the flat surface of walls make much powerful vortices around the sharp edges and the large area of wind shadow in the separated flow region. That is not suitable for the outdoor acitvities. So the bended walls are shaped into curved form which could let the wind esaily and smoothly go through in various directions, which means, as the BPS shows, these volumes could fit various directions of prevailing winds of four seasons. At last, the outdoor terrace could provide excellent platform for the outdoor activities which is welcome by the native.

Scheme 2

In contrast to the scheme one, scheme two presents an opposite image. Firstly, the volume is shaped into a complete and curved form by wind, which can reduce the amount of vortices as the wind goes through. Because, as shown in the prototype comparisons of different shapes conducted by BPS of ventilation, this way reduces the vortices effectively, which contributes to protect the surroundings from the bad influence made by a brand-new building. After that, the whole volume is totally considered as a medium between pavement and garden. So one step further, this initial model is shaped into a continuous surface that does not figure out the fuzzy boundary between wall and roof, which makes it integrate smoothly into the landscape of urban green space. The continuous shape integrated into the ground and the roof can create a semi-underground or over-ground natural courtyard, which provide more outdoor space so as to improve and stimulate outdoor public activities. As the simple and fast simulation shows, this blanket-like shape can even create some regions of different wind speed in which can meet different activities' needs for ventilation.

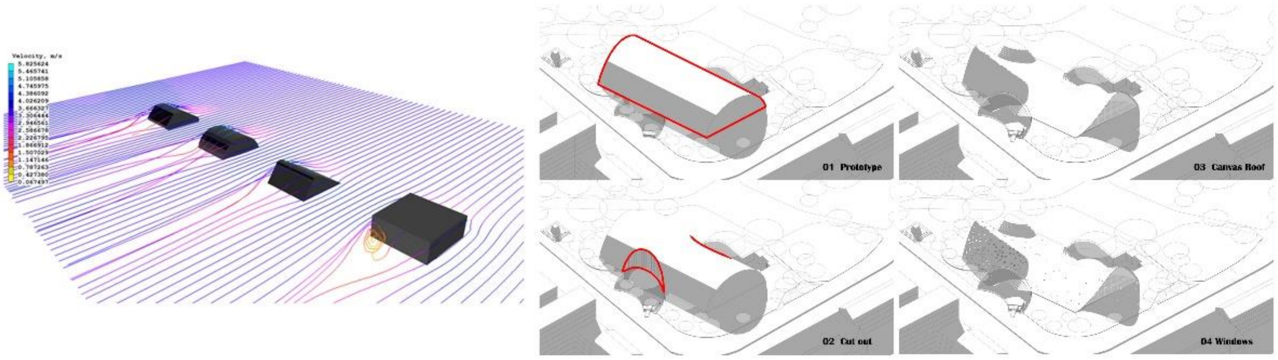

Fig. 5 Structure and windows

2.3.3 Optimization of Construction

The conceptual prototype is further developed in the phase of detailed simulation. The improvement is made mainly in two ways, they are structure design related to the sustainability and fenestration in association with interior daylighting.

Scheme 1

The unique separated form is supported by the continuous grid structure. The diagonally braced wooden structure allows column-free floor space, which is convenient for the indoor exhibition and other activities. Based on the grid structure, the rhythm of windows rangement is set. So the logical glazed facade with grid structure forms the rhythm of windows. According to the requirements for the level of daylighting in different functional spaces, windows are designed into various orientation, shape and density, which could meet the needs for different luminous environment and open up the building to views.

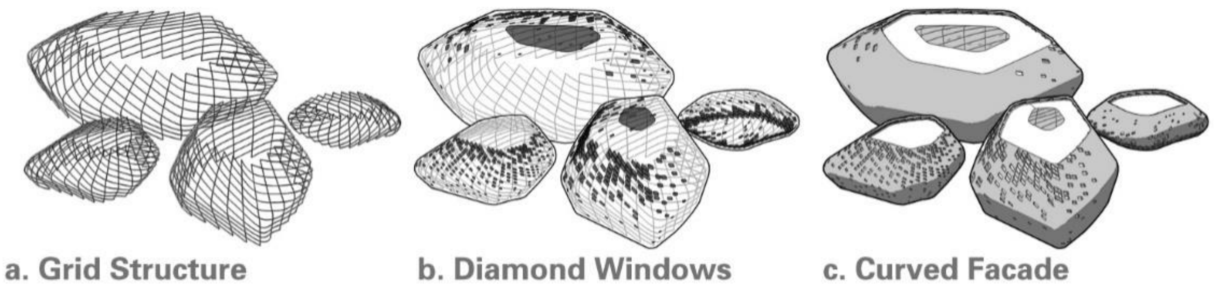

Fig. 6 Structure and windows

Scheme 2

Partly same as the design logic of scheme one, the volume in scheme two is supported by the streamline-shaped wood structure which ensures the stability, at the same time, to achieve the indoor non-column space. The double-skin roof can keep the interior in a good conditions with low energy consumption. The windows are set in the roof. Its arrangement is designed according to the distribution of direct solar radiation of all years to gain more solar energy in order to reduce the energy consumption.

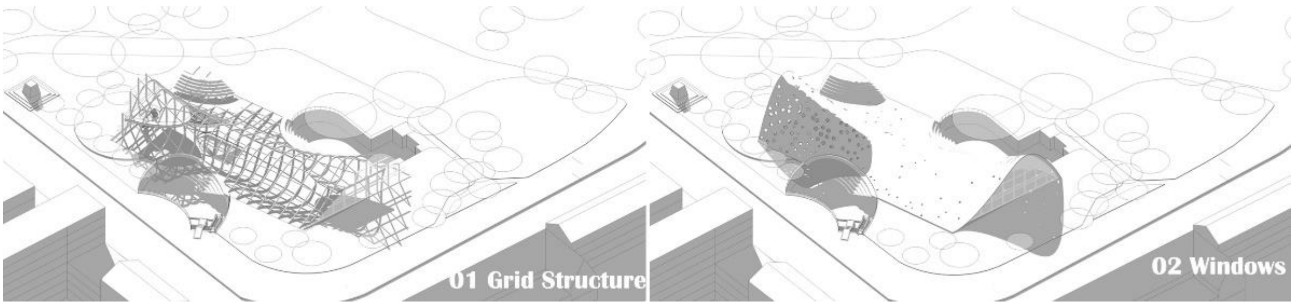

Fig. 7 Structure and windows

3. Results and Discussion

3.1 Results Comparisons and Process Reconsiderations

Notwithstanding the distinguished results, the two schemes above share the same workflow and strategy framework of BPS in the conceptual stage. Firstly, based on the climate analysis and site conditions study, the design strategies is set to protect the surroundings from the bad influence brought by the huge massing of a museum, especially in the terms of natural ventilation and outdoor activities. Under that direction, the initial form logic is to set a maximum volume partly underground which can leave enough space for the surrounding trees on the site, protect the quiet garden against the noise from main stream of people and leave more space for the outdoor activities.

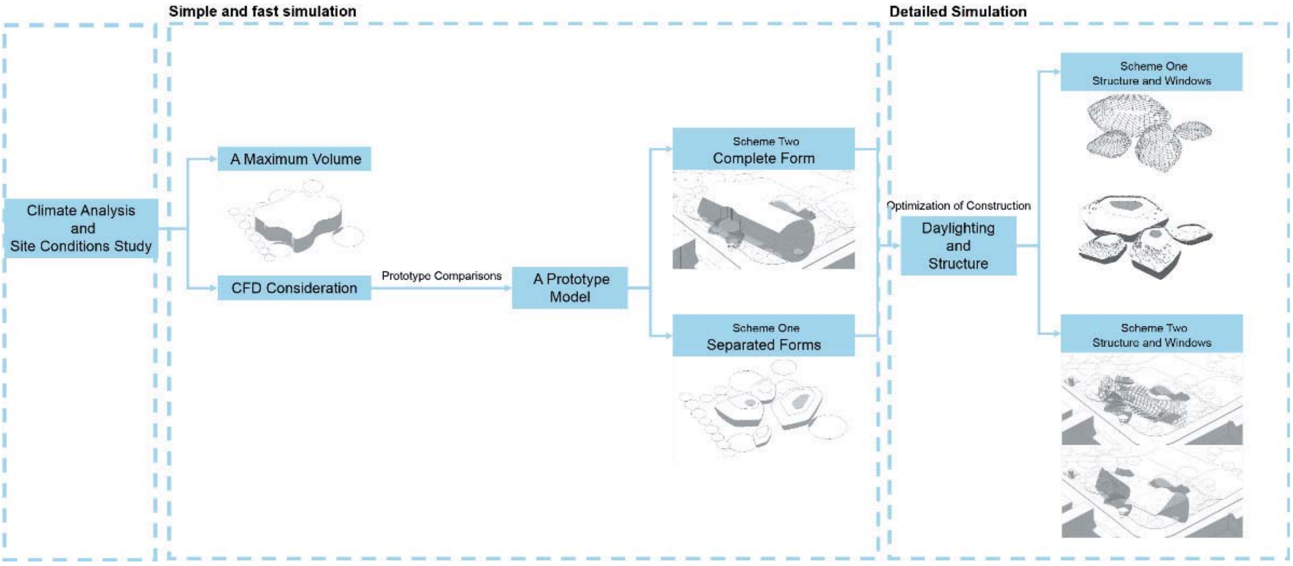

Fig. 8 Framework of museum design process

The next step is to develop the prototype model in the way of comparison in the phase of simple and fast simulation. According to different considerations, the model can be developed into two distinguished shapes – the separated forms and a continuous shape - with the same target of natural ventilation improvement and public space conservation. After the conceptual prototype, the detailed simulations could be made in two ways of daylighting and structure, which improves the design. The whole process is under architects' control and may be different because of the various aesthetic considerations.

3.2 Simple Form and Aesthetic Control

Above all, the strategy framework emphasizes the dominant role of architects' form creation and the effective assistance by BPS in every stage of design.
The framework shortens simulation processes and simplifies conceptual models so as to emphasize the performance drawbacks of form itself and leave enough space for architects in shape reconsiderations. So the framework suggests that it is still a typical thinking process of design concept and form logic based on the conventional architecture aesthetics, which provides the architects priority in the subjective control of the high-performance forms aesthetically and architecturally. To avoid the subjective judgment about the reality, simulation tools can provide the detailed quantitative statistics of the building performance and show some unknown form flaw under the seemingly reasonable design logic, contributing to the rational judgment about the design logic and the right suggestions in the wide range of possibilities among the form choices. So the conceptual model simplication in the simple and fast simulation phase can improve the experience of design with effective comparison.

3.3 Same Framework and Distinguished Results

The case experiment demonstrates that even the same strategy framework can definitely contribute to the toally distinguished results, which shows the possibilities of diverse design and aesthetic innovation. In this respect, we can see from the experiment that various deign strategies followed by the different design logic, and distinguished aesthetic conduction of archtects are the determinant. And the extension of case study database in the future can provide more inspiring information for this decision-making process.

4. Conclusion

The paper has describle a framework of BPS application and design workflow in the conceptual design. It is aimed to the analysis of workflow rather than the integrated design tools development, which contributes to establish the framework of sustainable design in the view of architects no matter what the simulation tools or design tools was used during the design process.

4.1 Strategy Framework

The strategy framework is established on the structure of sustainable design workflow which comes from the summary of case database. It is is divided into three phases, in which BPS could participate with different computational accuracy to support different design contents. The role of BPS in separated phases has been explicitly described as simple and fast simulation, detailed simulation and simulation evaluation. In each design phase, the calculation of BPS has to be directed by architects with different methods and professonals. The simple and fast simulation is most close to the design work with simplified simulation indicators and prototype comparisons. It serves as an adviser to helps architects make a decision in the conceptual phase rather than the only assessment tools in the final stage of design.

4.2 Future Research

The framework still needs more practice to testify and modify itself. Moreover, the case database in assisting with design process in early stage should be developed and enriched for further research. On the other side, some steps of the whole framework should be studied in a technical and systematic way for a detailed improvement. Uncertainty and sensitivity analysis of each strategy in the whole performance improvement and form creation, for instance, should be under research, which can determine the classification of impact. That will contribute to simplify the decision-making process in early stage.

5. Acknowledgements

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Success Criteria for Green Building Projects in the Nigeria's Construction industry: "The Stakeholders' perception"

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Summary

Green building projects design and construction are characterised by the problem of lack of shared perception and agreement on the objectives of the green building projects by stakeholders. The need and the cost for incorporating Green features varied among various stakeholders in the Nigeria's construction industry. Going by these characteristics, each stakeholder perceives the success according to a hierarchy of dimensions, which comply with his / her own agenda. The purpose of the study is to appraise the importance of success criteria for green building projects in the Nigeria's construction industry based on the clients, the end-user's and the construction professionals' perceptions. Research data was obtained through manually distributed research questionnaire. A total of 380 questionnaires were distributed and 200 questionnaires were returned and analysed statistically using Frequency counts tables, mean item score and Chi square statistics. The result showed that the top ten most important criteria for each stakeholder. In the overall analysis, there is a significant difference in the perceptions of the three groups of stakeholders in the green building projects with respect to their ranking of the project success criteria.

Key words: Green buildings, Stakeholders, Clients, End-users, success criteria etc.

1.0 Introduction

Various kinds of projects (construction, I.T., Telecommunication, Space, Oil and gas exploration etc.) come with different Goals, objectives, deliverables, phases, challenges, stakeholders and their various interests, requirements, targets, inputs and expectations etc. However, achieving this combination can determine project success or failure which may vary across the stakeholders involved in the particular project especially green building projects. Project stakeholders are impacted by the project in a positive or negative way. While some stakeholders may have a limited ability to influence the project, others have significant influence on the project and its expected outcomes. The ability of the project manager (PM) to correctly identify and manage these stakeholders in an appropriate manner is the difference between success and failure (PMBOK, 2013).

Projects that fail will affect the performing organisation because some aspect of its strategic objectives will not be delivered as planned; scarce resources will be wasted and individuals and groups (stakeholders) who had expected some benefit from the outcome of the project will be negatively impacted (Bourne, 2005). Sauer, 1993 outlined a different perspective linking project success with three dependent relationships called the triangle of dependence as follows:

i. The way an information system is fashioned through its project organization's activities;
ii. The project organisation requires support; and
iii. Supporters need a payback from the system.

The coalitions of an information system consist of those who do the work of design, development and operations as well as those who expect the end product will serve their needs or interests (ibid).

The insights offered by the triangle of dependence focus on the human aspects of project delivery and personal views of success. Project success or failure is strongly related to the perceptions of each individual project stakeholder and their willingness and ability to act either for or against the project. Therefore, failure could be supporters perceptions of expectations not met, or promises not delivered, or the belief that the support (resources) could be applied elsewhere. These perceptions are not necessarily based on logic, but often on the quality of the relationships between the project and its stakeholder's (Bourne, 2005).

It is critical for project success to identify the stakeholders early in the project or phase and to analyze their levels of interest, their individual expectations, as well as their importance and influence. Most projects will have a diverse number of stakeholders depending on their size, type, and complexity. These stakeholders should be classified according to their interest, influence, and involvement in the project (PMBOK, 2013).

Green building projects differs from conventional building projects in terms of siting, design, construction, operation and maintenance, efficiencies(Energy, Water, Lighting, IEQ, Envelope etc.) and impact on the built environment etc. (Greg Kats, 2003; USGBC, 2007; USEPA, 2009, Zane *et al,* 2009 and Dalibi, 2014). As such, Stakeholders' input, participation, roles and responsibility in Green buildings projects must be of high cognizance than conventional building projects because of the divergent stakeholders' interests, views on environmental sustainability, requirements, and successful delivery of such projects.

1.2 Research Problem

Green building projects design and construction are characterised by the problem of lack of shared perception and agreement on the objectives and success/failure of the green building projects by stakeholders. Such divergent or lack of shared perception and agreement ranges from:

- Incompatibility of interests among various stakeholders (Fenn et al., 1997),
- Absence of measured building performance data from currently operating sustainably designed buildings (BD&C 2003; ENSAR 2003; Andreau et al., 2004),
- Cost of green buildings in comparison with conventional buildings (Matthiessen and Morris, 2004),
- The believe that Incorporating green elements into building designs increase first cost and the impact of other factors which includes Building type, Location, Climate, Site conditions and the Project team. (Morris, 2007),
- Different Views regarding environmental sustainability and the built environment,
- Different Set of Criteria for success/failure for the project (Kumo, 2012) etc.

Going by these characteristics, each stakeholder perceives the success according to a hierarchy of dimensions, which comply with his / her own agenda.

1.3 Research Aim

The purpose of the study is to appraise the success criteria for green building projects in the Nigeria's construction industry based on the clients', the end-users' and the construction professionals' perceptions with a view of identifying the most important criteria for each stakeholder.

1.4 Research Hypotheses

The following hypotheses were formulated for this research; Chi- square statistical tool was used in testing the hypotheses:

- Null hypothesis (H_O); there is no uniform perception of Success Criteria by the stakeholders of Green Building Projects in the Nigeria's Construction industry

- Alternative hypothesis (H_A); there is uniform perception of Success Criteria by the stakeholders of Green Building Projects in the Nigeria's Construction industry

2 Literature Review

2.1 Success Criteria

Assessing project success has always been a subject of much debate because of the large number of criteria by which the various participants of a project would like to assess a project. In developing countries like Nigeria, there is substantial gap between the standards required and standard achieved in construction and trying to improve project based performance is always a challenge (Nguyen, 2004).

Odusami (2003), Defined success criteria as a set of principles or standards by which judgement is made while factors are a set of circumstances, facts or influences which contribute to the result. Success criteria correspond to the dimensions (or measures) on which the success of the project is judged whereas success factors are key variables that explain the success of the project (Diallo and Thuillier, 2004).

Nguyen,*et.al.* (2004), Identified six success factors and six success criteria. These success factors are; planning effort (construction), Planning effort (design), project manager goal commitment, project team motivation, project manager technical capabilities and scope and work definition and control system. The success criteria are; budget performance, schedule performance, functionality, contractor satisfaction and project manager/team satisfaction.

Bala (2000) opined that there indeed exist a distinction between a successful project and successful project management. Clients are more disposed to achieving a successful project rather than successful project management. The designers and the contractors, on the other hand, both expect certain profit and fee goals. However, all three parties desire to have the project on time.

Pinto and Slevin (1988) as cited by Kumo (2012), concluded that project success is a complex and often illusionary construct, but nonetheless it is of crucial importance to effective project implementation and it is suggested to have two major components: issues dealing with the project itself and issues dealing with the client. In addition, they stressed the necessity of developing an adequate target in terms of knowing when to determine project success.

The basic issue is that the set of criteria and the standard to be used may or may not be agreed by all the participants and stakeholders at the beginning of each project; even preference in any common outlined success criteria may differ among the various stakeholders especially with the divergent views on environmental sustainability, green construction and its impact on the built environment.

3. Research Methodology

Secondary sources of data such as journals, conference/seminar/workshop papers, text books, newspapers, magazines and internet etc. were used to review literatures on project success/ failure in the relation to green building field, which help identify and narrow success criteria among the various stakeholders. A *4-point Likert scale* questionnaire survey (as the primary source of data) was manually distributed to Clients, End-users and the various construction professionals in Nigeria selected through random sampling method. Frequency count tables, Mean item score and Chi-square statistics were used for data analyses. The top ten criteria for each stake holder were closely examined and compared to ascertain the similarities and differences on green building perceptions.

4. Data Presentation, Analyses and Results

4.1 Results from the Administered Questionnaires

The Primary data for this research work was obtained through manually distributed questionnaires to the stake holders and the responses were shown below.

Table 4-1: Stakeholder Respondents

STAKEHOLDERS	NUMBER OF RESPONSES	PERCENTAGE
Clients	70	35%
End-Users	65	33%
Construction professionals	65	33%
TOTAL	**200**	**100%**

The table below shows the fifty Success criteria used in this research; manually distributed to the stakeholders based on a 4-likert scoring category of 'Extremely' important, 'highly' important, 'important' and not 'important' with scores of 4, 2, 3 and 1 respectively.

Table 4-2: Fifty Success criteria for Stakeholders

Code	Criteria
C1	Client's Satisfaction
C2	Conformity of work to contract documents
C3	Initial identified objective attained
C4	Project completed on time
C5	Perceived performance and functionality
C6	Project achieved a high national profile
C7	Quality Compliance
C8	Environmental sustainability
C9	Project Completed within Budget
C10	Project design containing sufficient details
C11	Project consultants being responsive to questions and changes
C12	Client's interaction being open and friendly
C13	Aesthetics
C14	Communication flow being consistent
C15	Contractor satisfaction
C16	Meeting design, functional, technical, managerial and organisational goals
C17	Reduction of disputes
C18	Project management team satisfaction
C19	End-user satisfaction
C20	Good Reputation in the Industry
C21	Financial returns and project innovative features(outputs,mgt and design)
C22	Institutional or organisational capacity built in the organisation by the project

C23	Satisfaction of the objectives as outlined in the logical framework
C24	Technical innovation
C25	Additional Funding(Project)
C26	Project termination
C27	Schedule compliance
C28	Personal growth
C29	Health, safety and risk procedures being met with minimal accidents
C30	Commercial success
C31	Well defined scope of work
C32	Project being paid for as agreed
C33	Changes are being fairly introduced
C34	Supplier cost estimates being in accordance with client's requirements
C35	Project design containing sufficient details
C36	Project schedule being open and friendly
C37	Response to complaints being quick and productive
C38	Suppliers being able to meet deadlines
C39	Skilful sourcing of materials for construction
C40	Ability to use simple equipments for construction
C41	Conformance to standards of environmental management
C42	Commitment of contractor to environmental management
C43	Efficiency of project execution
C44	Preparing for the future
C45	Solving a customer problems
C46	Openness and friendliness in communication
C47	Flexibility for changes or modifications
C48	Green building Project Impact (savings in *running cost / cost in use*)
C49	Minimal defects in supplies
C50	Serviceability of the product

Source: Authors, 2015 based on Jha and Devaya (2009), Odusami (2003) and Kumo (2012)

The tables below shows the responses from seventy clients, sixty five End-users' and sixty five various project Professionals for green building projects with main focus on the top ten success cording to their criteria according to their respective perceptions.

Table 4-3: Top ten Success criteria based on the Clients' perceptions

Code	Criteria	Mean item score	RANK
C9	Project Completed within Budget	3.9143	1
C30	Commercial Success	3.8286	2
C48	Green building Project Impact (e.g. savings in *running cost / cost in use*)	3.6857	3
C8	Environmental sustainability	3.5429	4
C20	Good Reputation in the Industry	3.4000	5
C1	Client's satisfaction	3.3857	6
C50	Serviceability of the product	3.3429	7
C5	Perceived Performance and functionality	3.3286	8
C25	Additional Funding(Project)	3.3000	9
C29	Health, safety and risk procedures met with minimal success	3.2714	10

Source: Authors' field survey 2015

Table 4-4: Top ten Success criteria based on the End-Users' perceptions

Code	Criteria	mean item score	RANK
C19	End-User Satisfaction	3.9077	1
C48	Green building Project Impact (e.g. savings in *running cost / cost in use*)	3.8308	2
C41	Conformance to standards of environmental management	3.7846	3
C5	Perceived performance and functionality	3.7077	4
C50	Serviceability of the product	3.6769	5
C4	Project completed on time	3.6615	6
C8	Environmental sustainability	3.6462	7
C13	Aesthetics	3.6154	8
C6	Project achieved a high national profile	3.5846	9
C27	Schedule compliance	3.5231	10

Source: Authors' field survey 2015

Table 4-5: Top ten Success criteria based on the various project Professionals' perceptions

Code	Criteria	mean item score	RANK
C1	Client's Satisfaction	3.9846	1
C4	Project completed on time	3.9385	2

C21	Financial returns and project innovative features(output, management and design)	3.8769	3
C5	Perceived performance and functionality	3.8462	4
C18	Project Management Team satisfaction	3.8308	5
C2	Conformity of works to contract documents	3.7846	6
C48	Green building Project Impact (e.g. savings in *running cost / cost in use*)	3.7385	7
C15	Contractor Satisfaction	3.6769	8
C19	End -User Satisfaction	3.6615	9
C13	Aesthetics	3.6462	10

Source: Authors' field survey 2015

The top ten Success criteria for the stakeholders shown in table 4-3, 4-4 and 4-5 clearly indicate the following:

1. The ranking of the top ten set of success criteria among the stakeholders differ.
2. Success criteria *C48 for Green building Project Impact* (e.g. savings in *running cost / cost in use*) is the only uniform criteria among the stakeholders, this is attributed to this study on green building field.
3. Only few success criteria like Environmental sustainability, End-User Satisfaction, Perceived Performance and functionality, Aesthetics, Serviceability of the product, Project achieved a high national profile and Client's Satisfaction appear among the top ten of the of two stakeholders but on different rankings.

4.2 Testing of Hypotheses

The hypotheses formulated for this research work was tested using Chi-square statistics. The values for the mean item scores in table 4-3, 4-4 and 4-5 above were used as the data for the statistical computations with the result shown in the table below.

STAKE HOLDERS	**N**	**Level of Significance**	**D F**	**x^2cal**	**$x^2tab_{0.05, 18}$**
CLIENTS	10				
END-USERS	10	5%	18	0.0301	28.8693
PROJECT PROFESSIONALS	10				

With 18 degrees of freedom (DF) and 5% level of significance, the Chi-square tabulated ($x^2tab_{0.05, 18}$ = 28.8693) is greater than the Chi-square calculated (x^2cal = -0.8286). As such, the Null hypothesis is accepted; which states that "there is no uniform perception of Success Criteria by the stakeholders of Green Building Projects in the Nigeria's Construction industry".

5. Conclusions

From the Fifty Success criteria outlined for the Stakeholders in green building projects used in this study Shown in the tables above, it can be observed that the Clients, the End-users and the various project professional disagreed on a uniform top ten set of Success criteria for green buildings. Though, all shared the same success criterion "*C48" for Green building Project Impact* which is attributable to the scope and area of this research work.

However, few Success criteria featured in two out of three of the stake holders but on different rankings. This is further attested by the Chi-square statistical test which accepts the null hypothesis of the research. The Null hypothesis states that "there is no uniform perception of Success Criteria by the stakeholders of Green Building Projects in the Nigeria's Construction industry.

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Supporting urban district development by accompanying sustainability assessment

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Summary

One essential approach in the transformation of cities to improve their future proofness is the use of the principles of sustainable development. For selected issues, it may be an advantage to have as an object of assessment not the entire city but its parts (here urban districts). The paper discusses whether and to what extent an urban district development can be supported by the use of sustainability assessment systems. It presents partial results from the project Reallabor 131 Karlsruhe, while discussing the possibilities of combining a top-down and bottom-up approach in the selection of indicators and creating a typology of indicators and their description.

Keywords: sustainability assessment, urban district, existing districts, actor groups, indicators

1. Introduction

In the field of the implementation of the principles of sustainable development in the construction sector, a shift in focus from single buildings to entire cities and urban districts (urban scale) is present. This growing interest in sustainable urban development can be seen as a response to the growing importance of cities' environmental impact and the rapid increase in their population compared to the global average. For example, in the latest progress report of the UN-HABITAT II [1] it is clearly emphasised that the current urbanization model is unsustainable and unable to respond to many existing and emerging challenges such as: urban sprawl, congestion, pollution, emission of greenhouse gases, emerging urban poverty, segregation, increasing inequalities and other negative externalities. In this sense, new conditions need to be defined to achieve a transition towards an inclusive, people-centered and sustainable development.

However, achieving sustainable urban development is a complex and continuously-evolving task. One approach is to break up the "city" system into smaller units and involve "local stakeholders", i.e. local organisations, private actors, representatives of the local population, etc., in the development process and improvement of these units. In this case, local stakeholders are not seen only as people affected by the current urban processes and their socio-economic impacts, but also as collaborators, co-creators of the final decisions and implementers.

Urban districts and neighbourhoods have increasingly been proved as an appropriate level to implement sustainability principles in urban transformation processes. Thus, in the field of sustainable urban planning and governance at different scales, the neighbourhood or district represents a "meso" level of analysis and action between the city (including the hinterland municipalities) and single buildings (associated more directly with subjects such as the selection of construction materials and technologies, indoor comfort and safety, etc.). While at the city and building level both conceptual and analytical considerations have been dealt with since many years, neighbourhoods are increasingly moving into the focus of research and policy [2,3].

In the field of sustainability assessment, buildings initially constituted the starting point as being the smallest urban element of a human settlement. However, not only buildings, but also complex issues related to urban design and environment (e.g. optimal energy supply option, design of public spaces, etc.) as well as the interactions of people and how they use a place, influence the sustainability of the urban environment. Thus, the need to expand the sustainability scope and metrics to larger scales of the built environment leads to a more targeted focus on neighbourhoods or districts. Within the boundaries of neighbourhoods, different types of community and social networks are formed, functioning as intermediaries between local individuals, and offering in principle more opportunities for social and political expression or even active participation in collective decisions. Compared with the city scale, the level of involvement, engagement and motivation of different actors to participate in decisions influencing their living environment and conditions is higher in individual neighbourhoods, as residents are involved more directly and rather share the same living experiences [4]. In view of this, implementing interventions at a neighbourhood level appears to be an alternative and often more promising option for a transition to urban sustainability.

2. Sustainability assessment of neighbourhoods - Background

Up to now, several sustainability assessment systems and tools have been developed for urban districts and neighbourhoods, mostly as a result of the further development and adaptation of already established building sustainability assessment and certification systems to include the complexities of the urban scale [5]. Usually, these are suited for newly constructed districts, whereas for the sustainability-related improvement of existing districts, they are still too inflexible [6]. The most systems follow a performance-oriented approach (absolute assessment), failing in this way to reflect the dynamic and constantly changing character of an existing neighbourhood. Here, it is important to track and assess the progress over time towards a set of short-term or longer-term sustainable development targets, the so-called "distance to target approach". Additionally, municipalities often refuse absolute sustainability assessments, since they fear substantial disadvantages in case of a poor performance. An absolute poor score could potentially discourage the interested investors and developers and thus loose the chance to be improved in this respect.

Sustainability assessment should not be seen as an end in itself, but as an instrument to support sustainable urban district development. This is a process driven by various actors with different ambitions especially when it comes to the development process of an existing neighbourhood, compared to the planning of new neighbourhoods, where the main decision-maker is the neighbourhood developer.

In this context, the authors explore a sustainability assessment approach that allows for context-related identifications of key topics and target setting, and particularly the monitoring of the development progress. One basic advantage of this particular approach lies in its participatory model, as local actors are involved in the design of policies and objectives. The paper is based on experiences from the research project “Reallabor 131: KIT findet Stadt” (R 131).

3. Project “Reallabor 131 Karlsruhe” - Brief overview

The urban real lab project "Reallabor 131: KIT findet Stadt" ("Urban Transition Lab 131") deals with the sustainable development of the urban district "Oststadt" in Karlsruhe. It was initiated as a transdisciplinary research project of Karlsruhe Institute of Technology (KIT). In the project, besides the Institute for Technology Assessment and Systems Analysis (ITAS) and the Institute of Sustainable Management of Housing and Real Estate (ÖÖW), a number of other institutes of KIT are involved. The project is financed by the Science Ministry of the Federal State of Baden-Württemberg with duration of three years (2015-2017). The aim is to launch a joint transciplinary process through the integration of science, innovation and urban development together with the contribution of citizens and other local actors in order to develop a co-designed framework for a comprehensive sustainable development of Oststadt.

A sub-project of R 131 is concerned with the development, elaboration and application of a sustainability assessment system to accompany the further development of Oststadt. A “Reallabor” (or urban transition lab) represents a social context in which researchers perform interventions in terms of “Real experiments” so that to study and learn more about social dynamics and processes [6]. The aim is to allow social, technical, economic and ecological transformation processes that will ultimately lead to the sustainable development of the object under investigation - here a specific urban district [7,8].

To conduct research in a real-life lab within the context of sustainable development makes sense for a variety of reasons: Due to the transdisciplinary character of real experiments socially important challenges are addressed [9]. The scientists involved are working actively together with citizens on developing sustainable solution strategies. Using the knowledge they have acquired from the real experiments, further interdisciplinary issues can also be identified and reported. The researchers working in the real-life labs usually work together in interdisciplinary teams that increase the exchange of knowledge and experience between individual disciplines and allow the integrative handling of the respective topics. In addition, “real experiments” offer room for identification and testing of sustainable innovations under real (living) conditions.

The sustainability analysis and assessment in R 131 has three main objectives:

1) The working out and development of methodological foundations and an indicator system for a process-oriented sustainability assessment of urban neighborhoods/districts
2) A comprehensive sustainability analysis and assessment of the urban district Oststadt in Karlsruhe and the real experiments carried out in the sense of a testing and application of the methodological approaches
3) Development of a handbook on sustainability assessment and indicator development especially within the context of “urban transition labs”

The focus is on the development of appropriate instruments, such as indicators and indicator systems to describe and assess the sustainability and the progress and successes towards sustainable development.

4. Selection, description and use of indicators

4.1 Methodological approach for the selection of indicators

As Bell and Morse [10] point out, the selection and application of indicators is crucial for a systemic sustainability analysis, serving as a measuring and orientation tool for different actors to support activities to improve sustainability performances. Using sustainability indicators is associated with several key purposes. Basically, it should ensure or improve *information* through describing and measuring complex issues, *orientation* by revealing status, trends and deficits if so (early warning), *steering* by monitoring policy impacts, and *communication* by simplifying and summarizing complex subjects and data to support discussion and learning processes [11]. Taking this into account, the selection of suitable indicators from an abundance of possibilities existing by now is both essential and difficult. In any case, this should be based on a systematic application of criteria a few of which should be highlighted here: (1) appropriate concretion of sustainability criteria, to be adapted to particular thematic or regional contexts, in the case of R131 laid down in the Integrative Concept of Helmholtz and its sustainability rules [12,13]; (2) comprehensiveness and transparency regarding definitions, measuring units, data raising and calculation procedures, etc.; (3) the possibility to determine target values; (4) clarity of interpreting increasing/decreasing values as more/less sustainable; (5) sufficient data availability and quality [10]. Hence, it is obvious that indicators and their usage represent an important interface between a conceptual and an action level, and thus between science, policy, administration and societal groups among others.

Consequently, developing and applying indicator sets, as in the case of R131, faces several challenges and requirements as well. Definitely one of the most critical questions refers to the suitable number of indicators, best considering both objective of an appropriate description of subjects (tending to use more indicators) and manageability/communicability (tending to use less). Beyond this, a suitable combination of different indicator types should be selected (single, aggregated indices, spatially or socioeconomically differentiated, objective, subjective survey-based, etc.) which serve the purposes mentioned above differently.

Indicators and indicator sets can be obtained, on the one hand, from already existing international and national or regional approaches to the assessment of sustainability or sustainable development of cities and districts, including the new ISO 37120 [14] standard among others. A compilation and evaluation of various systems exists [15]. Here, the adoption and use of indicators from existing indicators systems at international, national or local level is referred to as a "top-down" approach. On the other hand, relevant issues and assigned indicators to these issues can be worked out and agreed on through a participatory process (bottom up) taking place in the district under study with selected stakeholder groups (residents/ homeowners, businessmen, companies, suppliers, interest groups, local authority, etc.).

The project combines the two approaches, "top down" and "bottom up", while also supplementing them with the experience of the authors in their role as moderators in the development of indicator systems/sets. Figure 1 illustrates this approach.

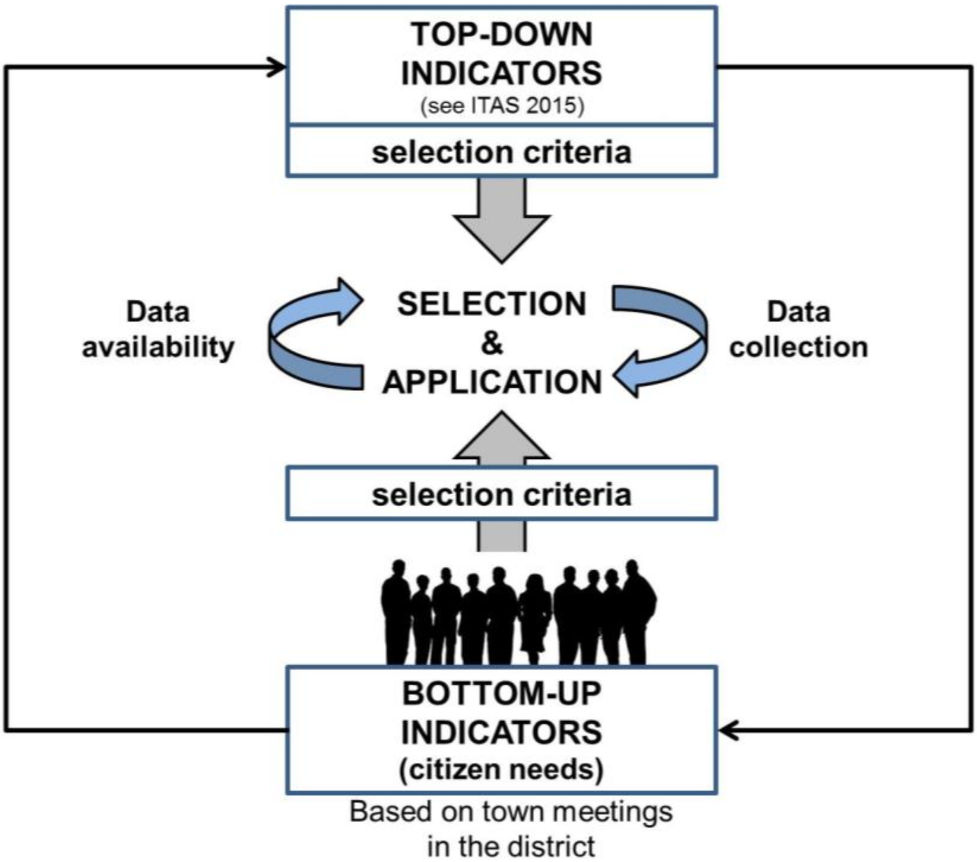

Fig.1 Illustration of top-down and bottom-up approach in the selection of indicators as part of a combined approach. (Source: Authors)

Without a doubt, the claim to implement a combined “top down”- “bottom up”- approach suitably raises questions such as to which extend and how stakeholders are to be included methodologically in which phases of selecting and using indicators. Furthermore, the determination of target values is essential, serving as reference lines to assess states, trends or policy successes and to improve planning security for actors. Finally, it is important to think about suitable ways to institutionalize monitoring and reviewing procedures that ensure decision and learning processes towards more sustainable development pathways. Starting from these considerations, the process of developing and applying indicators in R 131 is still ongoing. Already a basis has been developed for the creation of a typology of indicators and their description in the form of "fact sheets".

4.2 Basis for the creation of a typology and description of indicators

In the project the possibilities of creating a typology of indicators were discussed in detail. For example, it is important to distinguish between indicators that can be directly influenced by interventions of specific actors at a district level and indicators that can only be observed without being able to have any influence on them by actions inside the district. For instance, issues such as unemployment rate can be seen as important background information for understanding the situation in the district (observable, but not controllable), but these can be usually not affected/influenced by the stakeholders being active there. This leads also to consequences for target setting. Indicators that can be influenced directly (e.g. energy consumption for heating of residential buildings), can be linked to the goals of specific actors (here homeowners and energy suppliers) as well as their related opportunities for action. This is not the case for observable, but not controllable indicators. Table 1 gives an overview for a typology for indicators based on such considerations.

Table 1: Relevant aspects in the development and characterisation of indicators (Source: Lützkendorf).

Important information for the characterisation of indicators	**Examples / Explanations on the different possibilities of expression**
Type (what is shown)	Driving forces, pressures, state, impacts, responses
Statement (what is the level of measurement)	Source, midpoint, endpoint
The degree of influencability	Can only be observed (no influence) Can be indirectly influenced Can be directly influenced
Content	Economic, environmental, social, technical themes, overlapping themes
Target group	Public / residents, politicians, scientists
Requirement	Easily understandable Requires specialized/expert knowledge
Quantifiability	qualitative / quantitative
Time-related coverage	Refers to a certain point in time Refers to a certain period of time Temporal trend
Object of assessment	Entire neighbourhood/district Building stock Lifestyle of residents Etc.
Source / ability to generalise	Indicators from: * international system (ISO) * European system (CEN) * national system * regional/municipal system * sustainability assessment (DGNB)

For the description of indicators within indicator systems/sets the form of "fact sheets" has been proved to be effective. Here, it is important to mention the acting stakeholders and their options/opportunities for action in the description of indicators of assessment systems being intended for a process-oriented approach - see also table 2.

Table 2: Necessary information for the description of indicators (Source: Lützkendorf).

Information for the description of indicators	**Explanation**
Name / Title	
Definition	
Relationship with the general objectives of sustainable development	Allocation to the dimensions of sustainability
Relationship with the specific goals of sustainable district development	Importance of the indicator for the development of the neighbourhood, what should be fostered?
Object of assessment in detail	
Indicator type	Pressure, state, response, etc.
Measured variable	
Measuring instruction	

Measurement unit	
Reference unit	
Assessment scale	benchmark, limit value, target value
Positive direction of action	Is an increase or a decrease of the value a positive direction of action?
Can be influenced by … (actors)	Information on the actor groups that may have an active/direct influence
Can be influenced through … (measures)	
Influenced by …	Information on immediate causes and underlying causes
Has an impact on …	Information on consequences
Has interaction with …	Information on the interactions
Potentially conflicting goals/objectives	Information on goal conflicts
Source of information/data	
References to laws and standards	
References to tools	Tools for data collection and calculation
Proposals for action	Information on the options for action

4.3. The indicators under development

As part of considerations regarding the selection of indicators considerable differences between the bottom-up and top-down approach could be found; the perception and prioritisation of the various sustainability-relevant topics differ between these two approaches, since in the first case, it is based on scientific knowledge, while in the second case on the diversity of values and interests among local stakeholders. In addition, topics and problem areas could be detected in workshops with the help of residents that were not yet treated in the literature on existing sustainability assessment systems, but are relevant to the sustainability assessment at district level. These include, for example, opportunities for participation such as neighborly commitment; specific statements about the quality of outdoors activities, information services or the infrastructure for users of bicycles; plus potential of individual buildings for crossgenerational living. In this sense, the development of context-specific indicators to address the local site-related objectives plays a major role. This was to be worked out and discussed in detail during the project.

There are clear conflicts between individual sub-targets. For example, the use of wood in the heating with the aim of reducing the use of non-renewable resources leads to an increase in local emissions of particulate matter. Thereby, an indicator system also proves to be in general a suitable tool to identify conflicts between targets. Obvious conflicts were therefore included in the description of indicators - see table 2.

The table 3 below provides a selection of indicators currently under discussion in the project team. The full list will become a part of the project report. In the table the followings are presented:
* from which existing systems the selected indicators have been obtained
* on which approach their selection is based, top down or bottom-up?
* to which level they can be influenced

It is clear that the suggested themes and indicators by the local stakeholders are in some cases identical to indicators from existing systems. However, in other cases they represent specific reactions to current problems in the district (context specific approach).

Table 3: Indicators under discussion in the R 131 project team (selection)

Indicator	**ISO 37120: 2014**	**National level**	**State level**	**Municipal level**	***Top-Down***	***Bottom-Up***	**Can be influenced**	**Cannot be influenced**
Total residential energy use per capita (kWh/year)	X	(X)	(X)		X		X	
Share of renewable energy in final energy consumption in %	X	X	X	(X)	X	X	(X)	(X)
Greenhouse gas emissions measured in tonnes per capita	X			X	X		(X)	(X)
Total water consumption per capita (litres/day)	X				X		X	
Total collected municipal solid waste per capita	X		X		X	(X)	X	
Concentration of selected pollutants, e.g. PM 10	X	X	X		X		X	
Noise pollution	X		X		X	X	X	
Share of land used for human settlements and the transport infrastructure in the overall land use		X	X	X	X		X	
Share of public green areas in the total use	X				X	X	X	
Kilometres public transport system per 100 000 population	X		(X)		X		X	
Number of personal automobiles per capita	X			X	X	(X)	(X)	(X)
Number of physicians per 100 000 population	X		X	X	X		(X)	(X)
Number of homeless per 100 000 population	X				X		X	
Number of internet connections per 100 000 population	X				X		(X)	(X)
Evaluation of the possibilities for participation in the neighbourhood activities						X	X	
Investment rate			X		X		(x)	(x)
Economic value of the building stock	X				X			X
Unemployment rate	X	(X)	X	X	X			X
Number of registered associations per 1,000 residents				X	X		(X)	(X)
Reported crime to the police per 100 000 residents	X	X	X	X	X	(X)	X	
Evaluation of the quality of public spaces						X	X	
Assessment of design options and use of public spaces						X	X	
Number of barrier-free apartments						X	(X)	(X)
Evaluation of the possibility to network						X	X	
Public spending			X		X		(X)	(X)
Tax revenue	X				X		(X)	(X)

5. Discussion

In the development of indicators and indicator systems for accompanying and supporting sustainable district development through the use of a sustainability assessment system, typical thematic areas were initially established (energy consumption, water consumption, emissions, land use, etc.) However, it is important to complement these by indicators representing local challenges, problems and solutions. Furthermore, it is important to focus initially on indicators that can be influenced by actions of local stakeholders. The purpose of using sustainability assessment systems for the sustainable development (improvement) of existing neighborhoods is to support the goal-setting, the initiation of intervention measures/ activities and the determination of the success or failure of interventions.

6. Conclusion and outlook

The sustainable development of a city or a district is an ongoing process. It is possible and advisable to support this process through the involvement and participation of local actors/stakeholders. One tool is the development- and process-accompanying use of sustainability assessment systems. These can be used for the working out of “problem areas”, the determination of success factors and the development of strategies as well as their examination in terms of their success. It has been shown that the assessment systems aiming at certification are too rigid/ inflexible to be adapted to specific conditions in specific districts. It is imperative to involve local stakeholders and to take into account their interests. The authors see the solution to this situation in a "kit" for indicator systems, which combines the advantages of both top-down and bottom-up approaches. However, controlling the development of bottom-up indicators is a complex task. Such a process is now being supported and moderated in Reallabor 131 by the KIT project team in collaboration with the city of Karlsruhe and all involved parties at urban district level. Currently, the development of a methodological basis and the selection of indicators by the KIT interdisciplinary team are ongoing. In this specific case it is necessary to develop further and agree on bottom-up indicators, together with the actors involved in the urban transition labs. This will be achieved by carrying out specific surveys of certain groups of actors in the district. In this context, the residents’ general understanding of sustainability has to be investigated. In addition, “fact sheets” will be created for the appropriate bottom-up and top-down indicators and in consultation with the municipal administration and economic players the collection of data for each individual indicator will be pushed forward. Here, the problem of data protection has been proved to be a challenge that must be solved. One approach is the active provision and release of data through the residents and businesses in the neighborhood on an expressly voluntary basis - as a form of participation.

In the coming two years, the developed system will be evaluated and tested. The selection and application principles for the identified indicators will be further developed. The aim is to obtain a set of indicators both for the sustainability analysis of the district and the individual real experiments. In addition, it must be clarified which indicators are generally suitable for the assessment of urban transition labs and to what degree a contextualization is necessary.

7. Acknowledgements

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Sustainability assessment of building materials

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Summary

This paper assesess the evaluation of sustainability in the construction context. A userfrindly assessment tool for relative sustainability degree of building materials (PhD work of the author) is presented. Also it is added a new parameter to the tool, the "odor". The investigation shows how the rating is modified by the inclusion of this parameter and verifies if a building material that is considered sustainable could have a negative odor review. To see the diference about including or not the odor parameter the results of a case study are compared. The case study evaluates three different interior plasters to a standard solution: cement (REF); gypsum (A), clay (B) and lime (C).

Keywords: assessment; tool; building materials; sustainability level; odor

1. Introduction

There's been developed several sustainability measurements and evaluation tools or systems, which perform analysis on a global, national and building scale. There are a few tool types: LCA-Life cycle analysis, environmental declarations, labels and certification systems. Each one with its own specific objectives and scope. However, it is noted a reduced existence of a tool relative to building materials which can include broad criteria while being simple and clear for common users. The whole building assessment is of course important but has different goals then the focused view on the material choice, because it has the contact to the user. The human comfort criteria is highly influenced by the material choice. This kind of tool could be used by the designer himself, turning it into a real support for the planning process.

In this sense, we choose a tool developed by Bragança and Mateus [1] in 2009 that shows to be user-frindly and easy reading, which are also our main goals.
It was adapted in the PhD work of the author [2] into the scale of building materials with their specific requirements. The structure of this assessment tool compares several building materials and rates their relative sustainability level between each other. The analysis is supported by three main criteria: ecology, comfort, and economy. These criteria are built by specific parameters. Due to the normalization and aggregation of the raw data there will be a determination of a relative

sustainability degree of the materials. The evaluation reveals no absolute classification or label, but a comparative analysis between the building materials themselves. The results show if a particular construction material is better in comparison to a reference material or not.
As the comfort criteria is very important for the evaluation of building materials we added for this paper a new parameter, the odour, that influences a lot the indoor air quality. Humans living in Central Europe spend most of their time in buildings, therefor indoor air quality is important for human health and comfort. In order to preserve the air quality of the room, contamination should be as low as possible, therefor materials and objects used should be of low emission, i.e. they should give off as few pollutants as possible [3].

The building materials have the greatest impact, since they are used in big extensions. Emissions can lead to unpleasant odors and thus lead to dissatisfaction and lower productivity of the users. Through increased ventilation, the indoor air quality could be led to an acceptable level, but this increases the energy consumption. This connection between ventilation rate and odor-related emissions, makes the selection of suitable building materials an important aspect of energy efficiency for buildings.

2. Methodology

Sustainability is an issue that should be evaluated in comparison to the common practice - the standard solution - of a country or a specific location, thus making it possible to verify, for each parameter, if the analyzed solution has a better performance than the reference option. The minimum threshold of sustainability must represent the most expressive solution on the market and should be regularly adjusted according to technological development. The most sustainable solution depends on the state of the art at the moment [4].

The analysis is supported by three main criteria: ecology, comfort, and economy. These criteria are built by specific parameters, emphasizing relevant aspects of the case study. Figure 1 shows in a abstract form how the tool makes the comparison between the materials. Table 1 shows the parameters in each criteria.

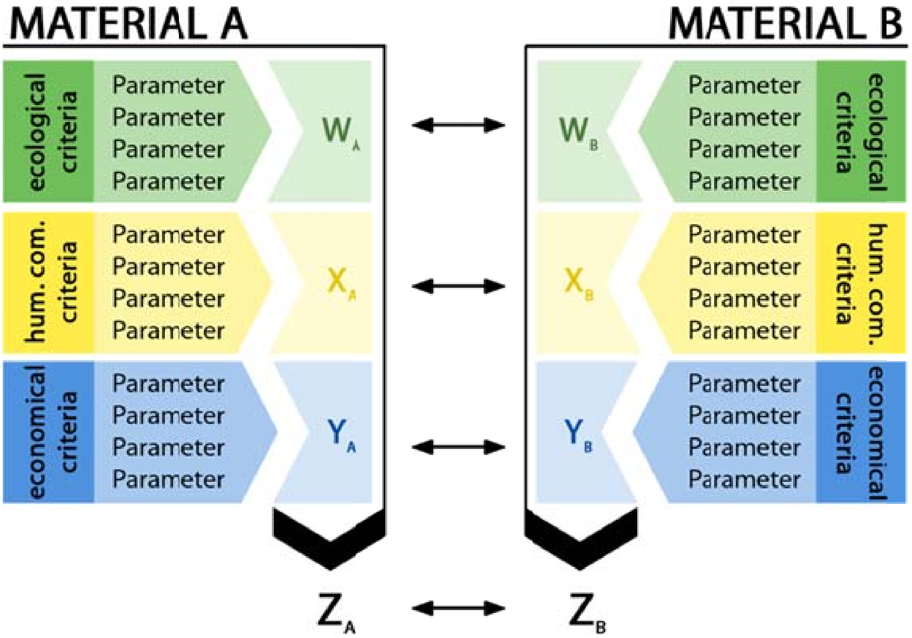


Fig. 1 Fluxogram of the assessment tool

Table 1: Parameters of the three criteria of the assessment tool.

Ecological criteria	Human comfort criteria	Economic criteria
OPD - ozone depletion potential (kg Ethen-eqv.)	AC – acoustics	CC – construction cost (€)
RMD - fossil raw materials depletion (MJ)	TC - thermal conductivity (λ)	DC – disposal cost (€)
GWP - global warming potential (kg CO_2-eqv.)	SC – security	
EP - eutrophication potential (kg Phosphate-eqv.)	DU – durability (years)	
AP - acidification potential (kg SO_2-eqv.)	HED – hedonics	
PIE - primary incorporated energy (MJ)	PI – perceived intensity (pi)	
IW - incorporated water (kg)		
SW - solid waste (kg)		
RP - recycling potential		
TT - transportation type/distance to the project (MJ/tonKm)		

The Data collection is the most important and delicate task in the evaluation process. The source from which the values are drawn must be scientific and independent, so that it does not influence the results of the analysis. It must be regularly updated and controlled by an external review to ensure its quality. Most of the data fonts are from public available databanks. The others are defined by different references or by scales witch were developed in the PhD work of the author [2].

2.1. The data transformation

After collecting all data it is transformed in order to make the comparison possible. It starts with a normalization of the raw data, in order to loss the different units and values. It turns the values into a scale between 0 and 1. According Balteiro, this process may be calculated as follows [5]:

- When indicator is of the "more is better" type, one should proceed as equation 1 and if the the indicator is of the "less is better" type, one should proceed as equation 2:

$$\overline{R}ij = 1 - \frac{Rj* - Rij}{Rj* - R*j} = \frac{Rij - R*j}{Rj* - R*j} \; \forall ij$$

$$\overline{R}ij = 1 - \frac{Rij - Rj*}{R*j - Rj*} = \frac{R*j - Rij}{R*j - Rj*} \quad (2) \forall$$

Rij is the real value, *Rj** is the optimum value, *R*j* the worst value and *Rij* is the normalized value. For better reading and comprehension, an aggregation of the various parameter values for each criteria is made. Thus, we obtain an abstract value that represents the relative performance of the solution at each criteria [4] [6]. The partial performance of the solution at each criteria (IS) is calculated according to the aggregation method presented in equation 3.

$$ISi = \sum_{j=1}^{m} {}^{p}_{j} \overline{R}^{p}_{ij} \forall i$$

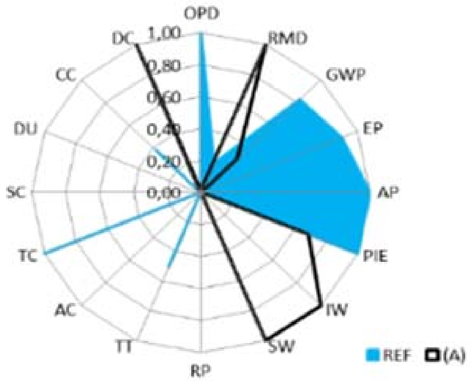
ISi is the weighted average of all previously standardized parameters of an indicator. There is no weighing between the parameters or the criteria, all should have the same impact on the global evaluation. Since the ecological criteria has more parameters, the result of the aggregation is divided with the number of parameters so that the value has the same weight.
After the criteria were individually assessed, the final result is achieved by adding the three criteria into one value. This value is the relative degree of sustainability of the considered building materials.

$$ISi = \overline{R}_{i1} + ... + \overline{R}_{in}$$

With this result, it is possible to compare the materials (A, B, or more) to the reference product (REF). There are three possible situations: REF > A, REF = A, REF< A. Also it gives the view of how big the impact or the achievement is related to the national common practice.
Due to the normalization and aggregation of the raw data there will be a determination of a relative sustainability degree of the materials. The evaluation reveals no absolute classification, but a comparative analysis between the building materials themselves. The results show if a particular construction material is better in comparison to a reference material or not.

2.2. Reporting results

Reporting the results is extremely important to bridge the last goal of this type of tool: simple and clear understanding of the results in order to ensure its practical applicability in the act of design to support as many people as possible.
Ensuring maximum use of this type of analysis is to present the final results as the sub results of each criteria, because there may be cases in which some values could override the ratings of other criteria in the calculation of the final value. Due to the fact that numbers are not intuitive to interpret, it is proposed a data graphic representation as "radar", which is illustrated in the next figure. The centre corresponds to the 0 and means the less negative impact, the edge is the most negative value, so the smallest stain is the material with better evaluation.



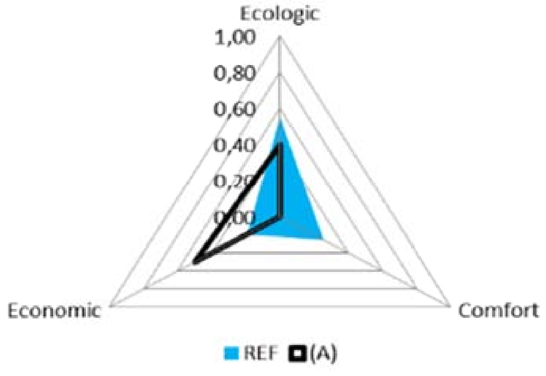


Fig. 2 Example of sub results (parameters and criteria); REF is the reference material (blue), A the material that is compared (black bold line)

2.3. The oudor assessment

For the odour assessment is used a sensory-based evaluation method system which uses threshold values for awarding the AgBB scheme and the Blue Angel. The AgBB scheme (Ausschuss zur gesundheitlichen Bewertung von Bauprodukten) was developed in 2003 in Germany. It describes a test and an evaluation concept for emissions of volatile organic compounds (VOC) from building products and establishes adequate requirements for health compatibility of the products. But the used method goes father then this by evaluating the Hedonic and the Perceived Intensity.

The hedonic note (HED) represents the emotional effect of the odour. It describes whether an odour impression is perceived as pleasant or unpleasant. The hedonic note of an odour represents the average assessment of a panel. The graduated scale shown below can be used to assess the hedonic smell effect. To avoid different interpretations, the terminal points and the middle of the bipolar scale are marked accordingly. The evaluation is carried out using the 9 -step scale from extremely unpleasant (-4) to “extremely plesent” (+4) [3].
The perceived intensity (PI) is determined with a trained panel using a comparative scale to the reference material acetone. The smelling capacity varies from human to human. Use of comparative sources ensures that the influences of subjective perception of the test result is reduced since all panel members evaluate air quality based on the same scale [3].

2.4. The case study

This case study compares tree plaster possibilities (gypsum (A), lime (B) and clay (C)) to a standard solution (cement – REF) for an standard office building in Berlin. These materials were chosen because in a current research project [7] they show to have the significant impact (when used as a finish layer) on the odor in the rooms.

Plasters based on lime were the main form of plastering and settlement until the arrival of cement. Cement is a binder that provides additional strength and ease in application, as well as a speedy execution, thus taking the place of primary binding materials for contemporary mortar. However, it is noted that sometimes cement is too hard, especially in cases for replacement in existing buildings. The lime-based mortar on the other hand, allows for more deformable behaviours, but it is also more expensive, has a long curing phase and has to have two layers.
The gypsum plaster has also a big role in construction business because it is fast, easy to use, it only needs one layer, is relatively cheap and absorbs moisture with almost no tension fractures.
The last plaster that we want to compare as well, is the clay plaster, that is a vernacular material, but currently it is used as an alternative because it absorbs and releases moisture creating a good indoor environment. It is not waterproof, it needs two layers and sometimes occur tension cracks (which are easy to remove) and it is expansive.
After exposing these differences, it is relevant to make a comparative analysis between them to check the three scopes that form their related level of sustainability.

The data sources are thoroughly listed in the PhD work of the author (de Lima, 2014).
The parameters for the assessment are listed above, in the first analyze without the odor parameters: the perceived intensity and the hedonic, and in the second time with them included. The aim is to conclude witch plaster has the best relative sustainability level in this case and to understand the role of the odor parameters has for the comfort criteria and how much the final value changes by including this parameters.

3. Results

3.1 Results without the odor parameters

The table below show the values for each criteria and the final relative sustainability level for each material. This results are generated after the normalization and aggregation of the raw data.

Table 2: Raw data (all parameter and units listed above).

OPD	RMD	GWP	EP	AP	PIE	IW	SW	RP	TT	AC	TC	SC	DU	CC	
5,7E-09	6E-4	0,19	8E-5	3E-4	0,15	0,23	0,64	3	1,3	2	1,4	1	50	15,8	1
1,9E-10	0,001	0,14	2E-5	2E-4	0,11	105	0,24	3	1	2	0,3	1	50	12,5	6
4,1E-09	5E-4	0,21	3E-5	2E-4	0,03	0,17	0,51	3	1,6	2	0,8	1	50	16,4	1
1,1E-10	5E-4	0,11	8E-5	2E-4	0,11	57	0,39	3	1,6	2	0,6	1	50	21,3	1

Table 3: Data after normalization (parameter).

OPD	RMD	GWP	EP	AP	PIE	IW	SW	RP	TT	AC	TC	SC	DU	CC
1,00	0,20	0,82	0,90	1,00	1,00	0,00	0,00	0	0,5	0	1	0	0	0,38
0,02	1,00	0,30	0,00	0,00	0,69	1,00	1,00	0	0	0	0	0	0	0,00
0,73	0,00	1,00	0,16	0,00	0,00	0,00	0,33	0	1	0	0,5	0	0	0,44
0,00	0,00	0,00	1,00	0,00	0,69	0,54	0,63	0	1	0	0,29	0	0	1,00

Table 4: Data after aggregation (criteria) and final relative sustainability level.

	ecological	comfort	economic	final level
REF	0,54	0,25	0,19	0,98
A	0,40	**0,00**	0,50	0,90
B	**0,32**	0,12	**0,22**	**0,67**
C	0,39	0,07	0,50	0,96

Figure 3 show the sub results of the assessment. The first compares the REF to A (REF is blue) were we see the different classifications. The second graphic is the same but the comparison is made between REF and B and the last shows the results for REF and C. The values are taken from table 4 and shows the sub results after the normalization. The figure 4 show like figure 3 the comparison between REF-A, REF-B and REF-C, but now there are represented the values for the criteria.

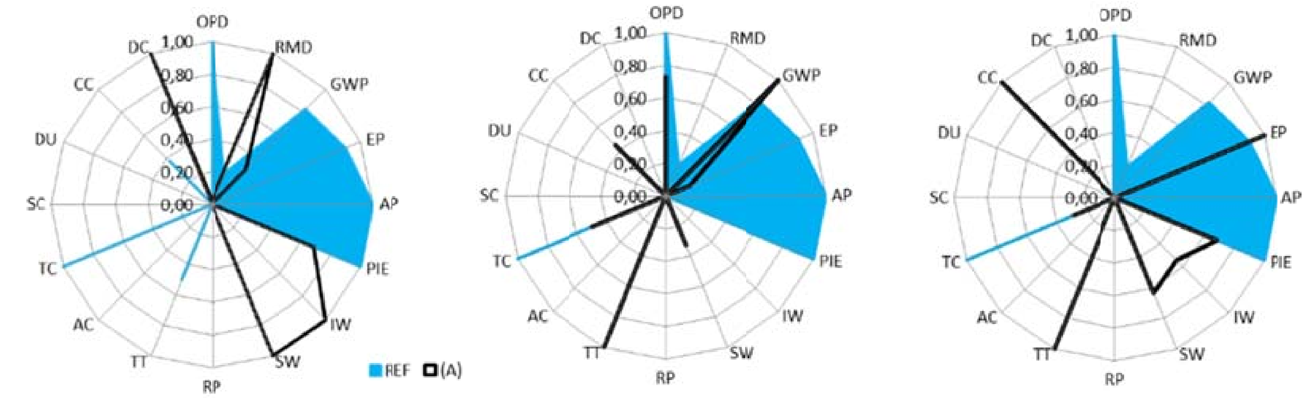


Fig. 3. Graphic results with all parameters (after normalization); (a) REF and A; (b) REF and B; (c) REF and C.

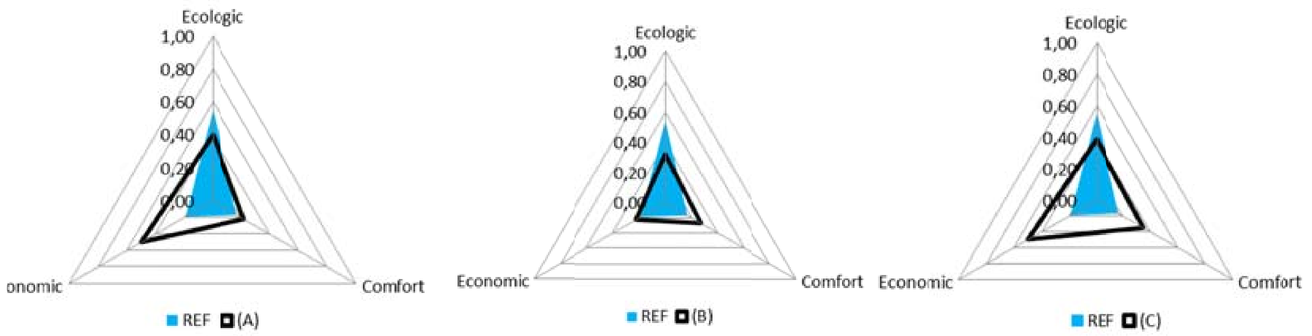


Fig. 4. Graphic results with criteria (after aggregation); (a) REF and A; (b) REF and B; (c) REF and C.

The results show that B (lime plaster) has the best final level classification. When we look to the sub results we see that B isn´t the best in all three criteria, only for the ecological. The REF (cement plaster) is the cheapest but also the worst in the ecological and comfort criteria, it has the worst final level. This indicates that almost all other three materials are better options than the REF. A (gypsum plaster) has the best comfort criteria, when we look to the individual parameters that build the criteria we notice that all materials only defer in the thermal conductivity parameter, which is a not very significant parameter because the plaster layer is really thin. So it is questionable if we should prefer it to the other hypotheses. The C (clay plaster) has an interesting result, it is the second best in ecological and comfort, but it is very expensive. If we consider that market prices vary and depend on the demand, maybe this option will have more demand in the future.
The decision what material to choose belongs still to the designer, that could evaluate according to the type of project and its specific objectives.

3.2 Results with the odor parameters

The table 5 shows the values for each criteria and the final relative sustainability level for each material with the inclusion of the two odor parameters.

Table 5: Data after aggregation with odor parameters (criteria) and final relative sustainability level.

	ecological	comfort	economic	final level
REF	0,54	**0,17**	0,19	0,90
A	0,40	0,22	0,50	1,12
B	**0,32**	0,27	**0,22**	**0,81**
C	0,39	0,35	0,50	1,24

The next figures (4 and 5) show the comparison between the materials, but including the two odor parameters.

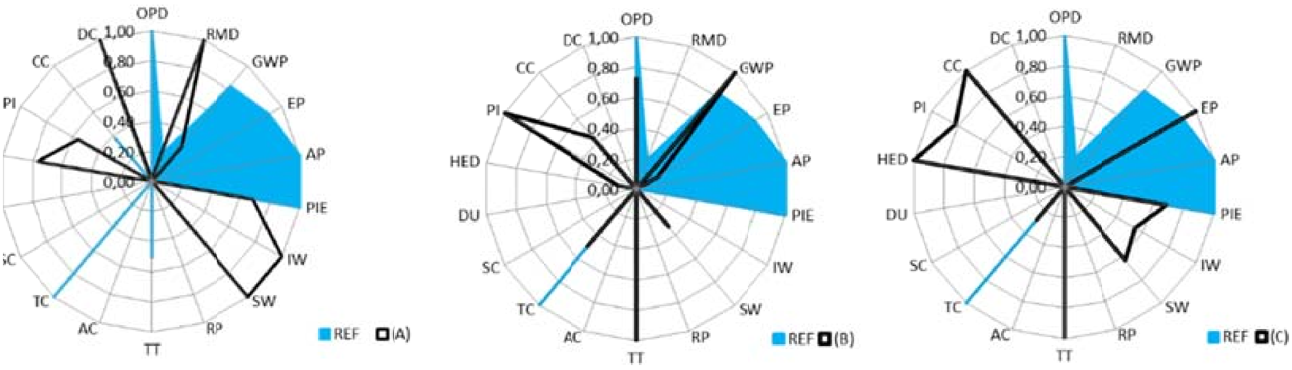


Fig. 5. Graphic results with all parameters (after normalization); (a) REF and A; (b) REF and B; (c) REF and C.

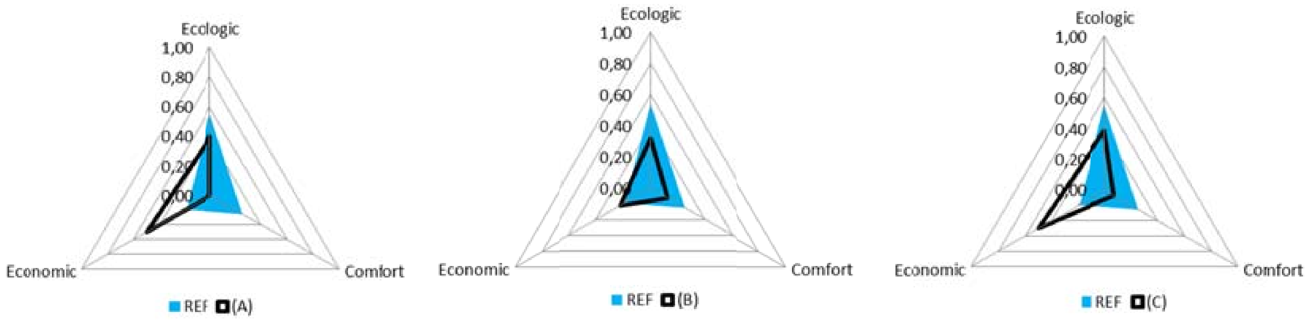


Fig. 6. Graphic results with criteria (after aggregation); (a) REF and A; (b) REF and B; (c) REF and C.

4. Discussion

The results show that B has the best final value even with or without the odor parameters. The best and the worst values change their variation, the level has decreased: in the case without odor parameters they are between 0,67 and 0,98, by including them it changes to 0,81 and 1,24. The comfort criteria changed significantly the order: REF had the best evaluation when the odor parameters are included, but the worst when they are not considered, C that has the second best value without odor parameters and gets to the last place when they are considered. In the ecological criteria they are all better then the REF, but REF is the cheapest (this could be caused, because it is the most used).

With the odor parameter the material with the best final classification has an 18% gain in the ecological criteria a 13% gain in the comfort criteria and a loss of 3% in the economic criteria. When

we add the odour parameter the value of the comfort criteria chance to -10% so the whole scenario changes.
The data are drawn from sources of scientific and independent character, without any attached commercial conditions [2], however this is the most critical point in the analysis, because the results are sensible to the quality of the raw data.

5. Conclusion

It is extremely important to take into consideration that the obtained results depend on the considered parameters, because results could differ by choosing other. The possibility of introducing other parameters that better suit the object of study in analysis, giving it another perspective, so it shows to very important to choose well the parameters that are important in the case study. For example it makes sense that in an office, were you stay at least 8 hours of your day, the odor is more important than when you choose the material of an exterior finishing of the wall.

The holistic view of the tool is very evident and tries to find balance between the tree criteria, even if the final decision stays by the user. The practical utility of the tool is that it is user friendly, applicable in various stages of the project and includes the multidisciplinary character of sustainability. It is user friendly because the introduction of the raw data is easy and the results are also easy to interpret, the graphic design facilitates the user to distinguish between the general classification and the partial results, allowing, in a specific case, to decide whether a deficit is relevant or not, or whether or not it could be easily resolved.
Its practical usefulness could be used by private designers or maybe be included in certification tools for buildings, that could use it for their “material" parameter, to make it more assertive.

6. Acknowledgements

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Sustainability elements in the Danish Building Regulations

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Summary

The general framework for new buildings in Denmark is set by the Danish Building Regulations. The building sector experienced a growing market demand for buildings with sustainability standards above the Building Regulations level and therefore the voluntary sustainable building certification system with the national adaptation, DGNB system Denmark, was launched in 2012. The Danish Energy Agency, which is the authority responsible for the Danish Building Regulations, wished to assess how well sustainability aspects were already covered by the Danish Building Regulations and what central sustainability aspects were lacking in order to ensure sustainable development of buildings in Denmark. The results of the assessment carried out in year 2013 showed that many sustainability elements are already incorporated, but it also clearly indicated the need for greater efforts, particularly in relation to information through practical guidelines and the development of national tools.

This paper provides an overview of the sustainability elements already included in the Danish Building Regulations and to what extent they are covered. Furthermore, it includes an overview of the elements that were pointed out in the assessment as elements that should be included in the regulations in order to ensure holistic sustainable development based on a balance between environmental, social and economic sustainability. The paper concludes with a brief update on current actions towards a more sustainable development in the Danish Building Regulations.

Keywords: Building regulations, sustainable buildings, sustainability tools

1. Introduction

Since the Bruntland Report "Our common future" was published in 1987 there has been a growing focus on sustainable development [1]. Sustainability is based on an equal balance between economic, environmental and social aspects. Generally, assessments of sustainability must be based on both a life-cycle approach and a long-term perspective. This paper uses the same definition.

Focus on the importance of sustainable development in the building sector is intensifying. The reason is the enormous potential that sustainable development in the building sector can have on the environment, society, business and users in a European context, where the construction market accounts for 10% of GDP and 7% of the workforce [2]. The construction and use of buildings in the EU account for about half of all extracted materials and half of the energy consumption and about a third of the water consumption. In addition, the building sector generates about one third of all waste in the EU and is associated with considerable environmental impact that arise at different stages of a building's life cycle [3]. Europeans also spend 90% of their time indoors and therefore the quality of the indoor environment of buildings is important for people’s well-being as well as their productivity. The great impact from buildings calls for further focus and development of sustainability within the building sector.

A holistic life-cycle approach is perceived as an essential part of the assessment of sustainable buildings. Furthermore inclusion of the sustainability aspects already early in the design stage is very important, as the ability to influence design is higher early in the project startup and early changes are more cost effective. It is therefore an important task to educate the building sector about the importance of the life-cycle approach, which will ensure that the long-term perspective will become a natural part of the mind-set for the design of buildings.

Buildings consume large quantities of resources, in particular materials and energy, which makes the growing focus on resource efficiency centre on buildings. To use resources more efficiently throughout the lifetime of a building, designers, contractors and also users need reliable evidence-based information regarding resource consumption and the resulting environmental impacts at all life-cycle stages [3]. Within the life cycle, the materials are followed from their extraction, to processing and leading to construction products that are part of the building, and through the building’s operational phase to an end-of-life scenario where the product can be replaced and recycled or landfilled. Life Cycle Assessment (LCA) is used to assess a building's resource consumption and potential environmental impacts and combined with an assessment of the lifetime costs of the construction and operation of the building. Similarly, Life Cycle Costing (LCC) is used to assess buildings costs over a building’s life cycle. To make these assessments, both tools and data are needed.

Within the EU, the committee CEN/TC 350 Sustainability of construction works is responsible for the development of voluntary horizontal standardised methods for the assessment of the sustainability aspects for new and existing construction works. CEN/TC 350 is based on a life-cycle approach and provides sustainability standards from an overall general level, to building level and for the environmental product declaration of construction products [4,5,6,7,8]. Therefore, these standards are closely related to the Construction Products Regulation [9].

The legislation in all EU member states is also affected by directives and regulations. One example is the the Directive on the Energy Performance of Buildings, EPBD [10]. Its implementation in EU member states is followed closely and it has already been implemented in the Danish Building Regulations [11]. Another example is the Construction Products Regulation, CPR [9] from 2011, which sets harmonised conditions for the marketing of construction products and is the replacement of the former Construction Products Directive, CPD [12]. The change from a directive to a regulation is intended to ensure harmonised legislation within the EU in relation to CE marking of building products. Buildings and constructions are the end product for building products so CPR provides a list of basic requirements for construction works, BWR, which is a revised version of the requirements in the former CPD. The main changes are that the BWR now considers the entire life cycle and has a clear focus on environmental assessment, use of natural resources and health and safety for involved persons. The BWR also constitutes the basis for the preparation of standardisation mandates and harmonised technical specifications.

Both CEN/TC 350 Sustainability of construction works and the CPR has a strong focus on the life-cycle approach. The life-cycle approach is an incorporated part of sustainable development along with the long-term perspective. However this is one of the challenges in relation to the Danish Building Regulations 2010, BR10 [13] where the focus has mainly been on the construction and not the use phase expect for the energy use for integrated building installations.

Currently, the goal for BR10 is to ensure a minimum quality of Danish buildings. The minimum quality is the result of principal political decisions on the lowest acceptable building quality for new dwellings, schools and offices. Building tradition and building regulations have developed over time. The first Danish Building Regulations from 1961 were mainly based on practical experience and building tradition combined with the first nationwide energy requirements. Since then, a strong focus on energy requirements has kept up with the development of the regulations. Earlier the regulations were based on specific detailed requirements but this has been changing towards functional requirements and in the latest versions the proportion of functional requirements increased at the expense of the number of specific detailed requirements. BR10 [13] includes technical requirements for a wide range of topics like, design, layout and accessibility, structural requirements, fire safety, indoor climate, energy consumption and building installations and services.

The purpose of this paper is to provide an overview of sustainability elements based on European standards in relation to the Danish Building Regulations [13], Construction Products Regulation [9] and the voluntary DGNB system Denmark for sustainability certification of buildings [14]. The analysis was carried out in year 2013 and is based on a wide range of sustainability aspects. This paper provides an overview of the sustainability elements already included in the Danish Building Regulations and to what extent they are already covered. Furthermore, it includes an overview of the elements that were pointed out in the assessment as elements that should be included in the regulations in order to ensure holistic sustainable development based on a balance between environmental, social and economic sustainability. The paper concludes with a brief update on current actions towards a more sustainable development in the Danish Building Regulations.

2. Methodology

The sustainability elements already included in the Danish Building Regulations are investigated based on the European CEN/TC 350 Sustainability of construction works indicators from the DS/EN 15643 parts 2-4. The three parts give indicators for assessing the performance of environmental, social and economic sustainability aspects. The indicators are listed in Figure 1.

BR10 has its legal basis in the Building Act. Therefore, the analysis will also include the Building Act to investigate whether the legal basis for the Danish Building Regulations supports further implementation of sustainability elements or whether there are areas where the Building Act needs to be revised in order to fully support sustainable development.

As BR10 currently sets boundaries for a wide range of topics, some of these also affect sustainability. The analysis goes through all the indicators of CEN/TC 350 to determine whether or not the indicator is incorporated in the current Danish Building Regulation or whether some topics are not yet part of the regulations.

In Denmark, the building sector and investors joined forces in a voluntary initiative to push for the establishment of a Danish green building council (DK-GBC) in April 2010. Meanwhile four certification schemes LEED, BREEAM, DGNB and HQE were tested on two recently built Danish office buildings in a research project [15, 16]. Based of the results of this project, DK-GBC supported by a wide range of steakholders in the building sector decided to use a nationally adapted version of the German certification system for sustainable buildings, DGNB. DGNB is developed by the German Sustainable Building Council (DGNB short for Deutsche Gesellschaft für Nachhaltiges Bauen) [16]. The DGNB system for certification is based on European standards. The nationally adapted system for Denmark is called DGNB system Denmark. The certification scheme ensures that sustainability is incorporated in certified building projects, and therefore it is relevant to include the DGNB system Denmark in the analysis and to compare it with the CEN/TC 350 indicators.

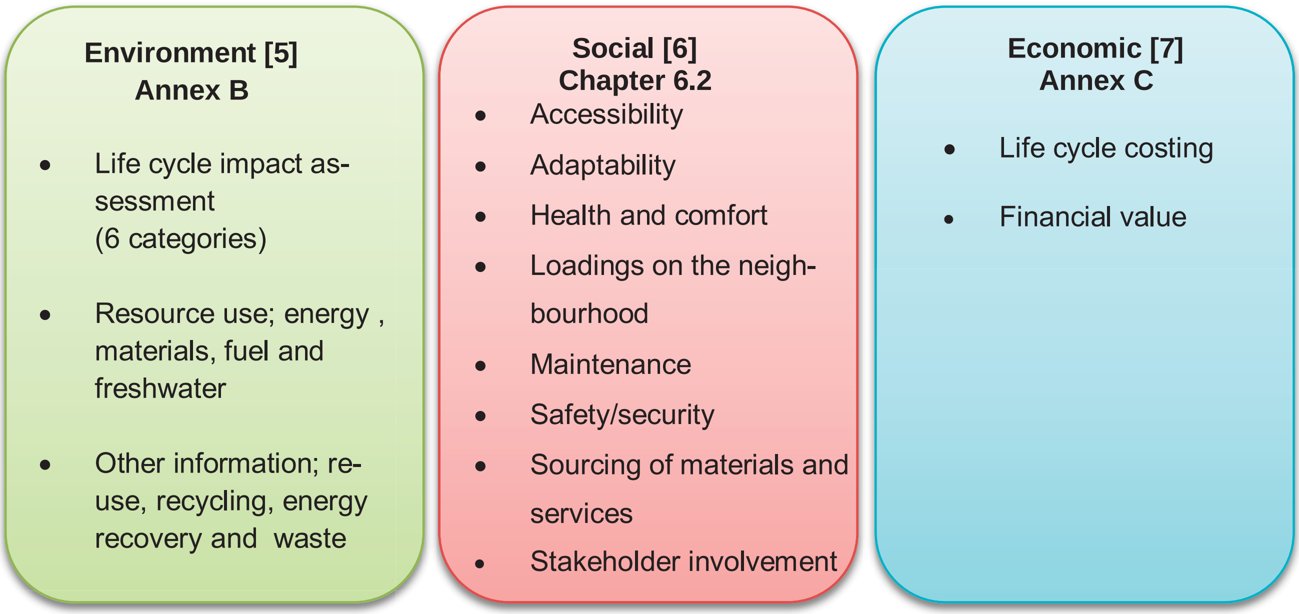

Fig. 1. Sustainability indicators from CEN/TC 350

Furthermore, the analysis includes experience from practise in Denmark to clarify, which sustainability elements that are or are not traditionally incorporated in building projects based on workshop input from the test of building certification schemes on two office buildings [16], which has not been reported earlier.

For buildings in the EU, the Construction Products Regulation, CPR is also very relevant especially in terms of the appendix with basic work requirements, BWR. The BWR consists of seven articles, which are listed in short here:

1. Mechanical resistance and stability
2. Safety in case of fire
3. Hygiene, health and the environment
4. Safety and accessibility in use
5. Protection against noise
6. Energy economy and heat retention
7. Sustainable use of natural resources

BWR applies to construction works, including construction products and materials used in construction works. Article 7 on sustainable use of natural resources is new for the CPR. CEN/BT/WG 206 ppoints out that BWR 3, 6 and 7 are linked to CEN / TC 350 Sustainability of construction works. The analysis also relates to the seven articles of BWR to CEN / TC 350 indicators for sustainability. The main focus of BWR 3 is related to CEN / TC 351 Construction Products - Assessment of release of dangerous substances. There the focus is on both the emission of hazardous substances into the environment and the impact on the climate. BWR 7 on sustainable use of natural resources is important in relation to sustainability of buildings in terms of use and reuse and life-cycle approach for assessments of buildings.

3. Results

An overview of the findings from the analysis are presented in Table 1.

Table 1: Overview of sustainability elemets of CEN TC/350 in a Danish context

CEN/TC 350 Sustainability Indicators	Danish Building Act	Danish Building Regulations	DGNB System Denmark	Experience from practise	BWR, Basic Work Requirement
LCA			X		X
Resource use	X	X	X	X	X
Recycling & waste	X		X		X
Accessibility	X	X	X	X	X
Adaptability			X	X	
Health & comfort	X	X	X	X	X
Neighbourhood		X	X		X
Maintenance	X		X	X	
Safety/security	X	X	X	X	X
Sourcing & services			X		
Stakeholders			X		
LCC			X		
Financial value			X		

3.1 Dasnish Building Act and Danish Building Regulations

BR10 is based on the Building Act but still there are differences in the coverage of sustainability elements. However, in relation to the sustainability indicators in CEN / TC 350 Sustainability of construction works, it is clear that especially the economic elements are not represented.

Especially the Building Act has a wider coverage within environmental and social sustainability. For a long period of time, the Danish Building Regulations have had a strong focus on energy consumption and indoor climate in buildings. Similarly, there has been an increased focus on the area of accessibility.

The Building Act does not deal with LCA, but it describes that unnecessary use of resources should be counteracted. The result is that there are no requirements to this in the Danish Building Regulations.

3.2 DGNB System Denmark

As the DGNB system Denmark is chosen as the national voluntary certification scheme, with important support from the steakholders within the Danish building sector, it is included in the analysis so it can be compared with the CEN/TC 350 indicators. In general, it is noted that the voluntary certification scheme DGNB system Denmark stands out as it covers all the sustainability indicators of the European standards on sustainability. The certifica-tion scheme also contains some additional criteria such as transport, outdoor areas, environmental impacts from the construction site and aesthetic quality.

3.3 Practice in Denmark

Information on experience from practice in Denmark was gathered parallel with the testing of the four building certification shemes. The reults show that the primary focus is on the sustainability aspects that need to be fulfilled in order to comply with BR10 for e.g. energy and indoor climate requirements. These are also often specific focus areas for the building owner, developer or users.

3.4 Construction Products Regulation, BWR

In general, it is noted that sustainability indicators in CEN / TC 350 Sustainability of construction works is also in accordance with BWR. However, there are some differences as the BWR does not make demands in relation to the adaptability and user control, or to traceability through the purchase of materials and services or to stakeholder involvement and the economic elements.

4. Discussion

4.1 Overview and definition

The analysis shows consistence between the DGNB System Denmark and the sustainability indicators of CEN / TC 350. This is a highly relevant result as it verifies that there is a mutual understanding of the term sustainability. The Danish Building Regulations does not contain information about the sustainability of buildings. Therefore, it is suggested to include a definition of sustainability in revised editions of the Danish Building Regulations. It might also be considered whether a sustainable development for new Danish buildings is so important for the building sector that it calls for a revision of the Building Act that will include the word sustainability.

Sustainability aspects have high priority for developers, users and building owners in practice. However, the lack of a clear definition of sustainability of buildings means that innovative sustainable solutions are abandoned for well-known traditional solutions. The building owner or developer has the option to choose a certification by DGNB System Denmark, which will ensure focus on sustainability in new buildings.

4.2 Regulations in practice

As sustainability is characterised by a broad holistic approach, the current focus points in the Danish Building Regulations may look like individual initiatives, where e.g. energy consumption and indoor climate lack coordination, so an optimisation of e.g. the indoor climate with increased ventilation will have a negative effect on the energy consumption and thus affect current practice. The same pattern is expected for builing regulations in other countries that do not have specific focus on life-cycle approaches and sustainability.

In practice, the primary focus is on the sustainability aspects that need to be fulfilled in order to comply with BR10. Therefore, implementation of more sustainability elements in subsequent Danish Building Regulations may prove to be an effective way to ensure a sustainable development in new Danish buildings.

An example of an area that has high priority for building owners when setting requirements for the design of new buildings is the heating demand, because this area has specific requirements in BR10. In addition, there are long-term objectives, which enable developers to implement planned subsequentenergy requirements. This option works in practice, as stricter requirements for heat consumption are often imposed in new buildings, compared with the current BR10. The subsequent planned and tightened energy requirements can be imposed by either the individual developer or by local requirements for spatial planning.

Indoor climate is another example of a sustainability aspect that is often requested by developers or clients. Although calculations are often performed for thermal comfort, daylight and maybe acoustics during the design process an earlier investigation has shown that in practice it is a challenge to ensure the documentation of e.g. thermal simulations [17]. In addition, indoor climate parameters are based on calculations but they are not compared with the actual indoor climate of the building when it is in use. Therefore, it is important also to ensure that sustainability aspects are documented.

4.3 Environmental assessment

The coverage of environmental sustainability has a limited focus on energy consumption, but the scope can be broadened by implementing a life-cycle assessment. However, to implement a life-cycle assessment, there is a need for; national data for building materials, environmental product declarations data, service-life data and a Danish LCA tool for assessment of buildings.

BR10 does not require life-cycle assessments, so it is rarely used. In the DGNB system Denmark certification for new buildings assessments, it is mandatory to perform LCA assessments, so as the number of certified projects increases, so will the experience with performing LCA for buildings. If LCA data can be assembled for various construction projects, this can create an opportunity for building designers to gain greater understanding of the importance of materials in relation to resources and environmental impacts. This knowledge can then be incorporated in the design process for new buildings in Denmark. It is necessary to support the ongoing development of data for Danish construction products, preferably in the form of the environmental product declarations (EPDs), and a complete list of estimated service life for building products that are suitable for Danish conditions. Moreover, there is a need for the development of a national tool for LCA calculations that is flexible and can ensure the quality of the performed LCAs on Danish buildings.

4.4 Social assessment

The social sustainability aspects for buildings are fairly well covered in Denmark, including accessibility, safety and security and health and comfort in terms of indoor environment. In Denmark there are requirements and standards and tools available to predict and optimise the indoor environment, requirements and regulations for safety in terms of fire codes and construction codes, regulations and tools available for building accessibility. Denmark also focuses on sustainable modes of transport, both public transport and conditions for cyclists.

In Denmark local requirements for spatial planning and environmental legislation regulates protection of a building's immediate environment against noise and emissions relative to neighbours. The local requirements for spatial planning also regulate stakeholder involvement in terms of neighbour hearings or public hearings.

However, the area of traceability in the procurement of products and services is not accounted for.

4.5 Ecomomic assessment

The analysis showed that neither the Building Act nor the Building Regulations contain economic sustainability elements. Economy is not part of the purpose of the legislation. However, there is a great opportunity to drive the development towards more economic sustainability. This may be supported by information, guidelines and a Danish LCC tool for the assessment of buildings and the data needed for it.

In Denmark, it is a problem that the economy is typically divided into capital cost and an operating budget, so that the economy is rarely observed in a life-cycle perspective. The lack of available tools that can help to show that the effect of the higher capital investments can be cost-effective due to lower operating costs, better quality and durability of the materials.

4.6 Sustainability in the Bacis Work Requirements

The analysis also covered the basic work requirements, BWR, which is applicable and in force for all EU member states. In general there is a wide coverage compared with CEN / TC 350 except for adaptability and user control, traceability through the purchase of materials and services, stakeholder involvement and the economic elements. Implementation of BWR 3 and BWR 7 is likely to have significant impact on the development towards more sustainable construction in Europe. In relation to BWR 3, there is also a need for further focus on hazardous substances in buildings.

The new BWR 7 on sustainable use of natural resources is interesting especially in terms of using a life-cycle approach. If we take a closer look at article 7 of BWR, it has three sub-points which state that constructions must be designed, built and demolished in such a way that the use of natu-ral resources is sustainable by ensuring; a) reuse or recyclability of the construction works, their materials and parts after demolition; b) durability of the construction works and c) use of environmentally compatible raw and secondary materials in the construction works. All parts of BWR 7 are important in life-cycle approaches and therefore this supports the implementation of LCA and LCC and a general focus on sustainable development.

5. Conclusion

The analysis performed in year 2013 examines how the Danish Building Regulations can support a development towards more sustainable buildings in Denmark. This illustrates which of the current requirements can help to ensure construction of sustainable buildings, and how supplementary requirements or guidelines may help implementation of further sustainable elements. Based on indicators of sustainable buildings from CEN / TC 350 Sustainability of construction works, these indicators were analysed in relation to the requirements of the Building Act, Building Regulations, DGNB system Denmark a voluntary sustainability certification scheme, Danish practice and the basic work requirements, BWR from the annex of the Construction Products Regulation.

There is consistence between CEN/TC 350, the BWR and DGNB system Denmark. This shows that there is a mutual understanding of sustainability in buildings and which of those elements that are important for buildings.

The basic work requirements in force for all EU member states have a wide coverage ccompared with CEN / TC 350 except for adaptability and user control, traceability through the purchase of materials and services, stakeholder involvement and the economic elements. BWR 7 on sustainable use of natural resources is interesting especially in terms of using a life-cycle approach, which may support implementation of LCA and LCC and a general focus on sustainable development. In relation to BWR 3, there is also a need for further focus on hazardous substances in buildings. Thus implementation of the basic work requirements is likely to have significant impact on the development towards more sustainable construction in Europe.

The lessons learned in Denmark are that a sustainable development is best supported by a focus on life-cycle approaches in combination with strict requirements in the national building regulations.

Denmark has come far in reducing energy consumption in new buildings, and there is sufficient focus on social sustainability in terms of indoor climate. There is a great need for specific requirements, standards and tools in relation to environmental sustainability by environmental impacts and resource use and also for economic sustainability. To implement a life-cycle approach for buildings, it must be incoorperated in all phases of design, construction, use and demolition.

Available tools and data are necessary for the implementation of a life-cycle approach, and this includes:

- Development of guidelines and tools for performing LCA and LCC in buildings
- LCA data for building materials used in Denmark, and especially for construction products that are produced in Denmark
- Knowledge of what materials are the most important in terms of environmental impacts throughout the entire life-cycle of a building
- Tables with service-lives of construction products under Danish conditions which needs to be included in the LCA and LCC
- General knowledge throughout the building sector for life-cycle approach for construction. This applies to building designers, those who perform the assessments, decision-makers and manufactures of construction products

A Danish guide on sustainable construction, will provide a higher level of knowledge and benefit the entire construction industry massively. Further knowledge, clear requirements and tools associated with hazardous substances in buildings is needed. Dissemination of that knowledge should lead to the substitution of dangerous chemicals in buildings. Initiatives that support the suggested needs are necessary to ensure a sustainable development in the Danish building sector.

Following the analysis, the Danish government in autumn 2014 presented a national strategy for buildings with five focus areas where one area is sustainability of buildings. This was followed by the launch of a guideline for sustainable buildings and two new tools and guidelines for life-cycle assessment, LCA and life-cycle costing, LCC in spring 2015. The tools can be downloaded for free and there is no license fee. The tools are supported by guides on both LCA and LCC [18].

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Sustainability profile of urban planning in Algiers

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Summary

In Algiers, the implementation of the new strategic master plan requires the definition of a framework for the conceptualization and assessment of urban quality. In this context, the present article proposes a tool for sustainable assessment -“Sustainablity profile”- which can lead to transformation and adaptation of a territory to the requirements of sustainable development. This evaluation study not only contributes to a better understanding of local challenges, but it provides also a decision support elements for planning and urban development. The application of the tool on a district of Algiers should allow both the implementation of its urban characteristics and the highlighting of its potentials and its dysfunctions. The methodological approach will lead to the formulation of a sustainability profile in order to help local actors to implement a sustainable management of their territory.

Keywords: Sustainable urban planning, local assessment framework, sustainability profile, Algiers.

1. Introduction

Sustainable urban development became an increasingly important issue in territorial and urban policies in Algeria. Planning instruments such as : National Scheme of town planning (SNAT), Master Plan for the Metropolitan Area (SDAAM), Master Plan of Urban Planning and Development (PDAU), have adopted sustainable development principles for the urban development strategy of Algiers. Nevertheless, the implementation and assessment tools for this strategy are still absent (Berezowska-Azzag, 2012). From a theoretical point of view, it is relevant to ask why we need tools to assess sustainable development, especially in urban areas?

An important feature of sustainability assessment tools is to make environmental, social and economic issues measurable objects using indicator systems - "what gets measured gets managed" (Bossel, 1999 ; Eggenberger & Partidário, 2000 ; Jesper, 2009). These assessment models, based on indicators, are considered as communication tools for both levels: internally (within the work team) and externaly (with all the actors and inhabitants) (Von Malmborg, 2003).

The emphasis on indicators and benchmarks is a way to make sustainable development an operational concept. Making sustainability a measurable object (Jensen & Elle, 2007) contributes to a wise integration of its objectives in urban projects. In the same way, the "tool-ification" (Jesper, 2009) and the "standardization" of sustainability emerge as the dominant trends in the conceptualization of sustainable urban development. In fact, sustainability is not only defined by tools and standards locally implemented, it is also increasingly integrated into traditional patterns of urban policies (Bossel, 1999; ARE, 2004). From these theoretical perspectives, we can assert that the reasons for the development of sustainability assessment tools are not only related to the understanding of a «common sense» of measurement and identification issues, but are also related to the integration of new types of policies based on voluntary participative and collaborative approaches, allowing, therby the implementation of operational objectives adapted to local urban issues.

Furthermore, the existing tools are quite often either adapted to the context or partially used. This flexibility is generally a necessity because of contextual differences and data availability for example. However, tools adaptation for some applications and contexts is part of the learning process. In many cases, it allows developing new versions of predefined tools based on contexts issues and specificity (Deakin et al., 2002).

2. “Sustainability profile” as assessment tool

Urban sustainability profile is one of the new decision support tools. Integrated upstream of strategies and decision-making process, this tool provides a three-dimensional image of the urban situation while defining local assessment criteria and indicators (Srir & Akrour, 2011). It can be global or specific (environmental profile, socio-economic profile, landscape profile, heritage profile); it also allows to measure sustainable development according to predefined objectives: static situation (time T), evolution (T1-T2) or monitoring (after achievement). Sustainability profile can be specifically considered as a shared diagnosis of sustainable development of a given urban situation (district, municipality or city) (Rouxel & Rist, 2000). It covers, not only the definition of the main urban, environmental and socio-economic issues, but also the definition of local stakes and development strategic goals. In addition, this tool allows the integration of evaluation and actions monitoring devices by defining indicators to measure the urban environmental performance (see Fig. 1). Through its comprehensive and integrated approach, the sustainability profile could represent a framework for various policies and urban actions for sustainable development either for environmental charters, local Agendas 21 or for planning and urban development instruments.

However, the difficulty of urban diagnosis is often not only linked to the unavailability of local framework that is essential for assessment practice, but is also due to the complexity of the indicator models construction process meant to be adapted to specific contexts. Indeed, indicators are the means of the profile measurement and presentation (Maclaren, 1996). They result from a prior understanding of the urban situation in question and they lead to the construction of a systemic model that reflects accurate reality of the urban environment and the interrelations that govern its implementation (Vandevyvere, 2013).

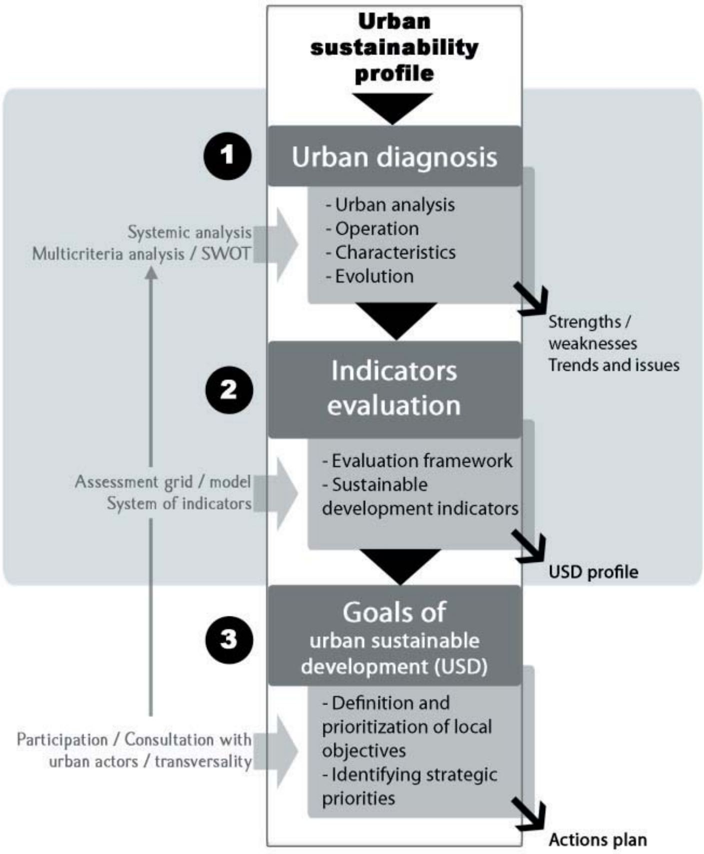

Fig. 1 Urban sustainability profile based on a local framework indicators

3. Methodological approach

3.1 Context

The main concern of Urban Planning and Development Master Plan (PDAU) of Algiers is to settle Algiers urban crisis achieving an improved urban environment quality (Wilaya d’Alger, 2011). This plan defines a strategy for requalification and urban valorization in order to make the urban planning and the territory management more sustainable. Integrated framework of sustainability needs to be both in harmony with the overall strategies defined upstream of urban policy (Urban Planning and Development Master Plan – PDAU, Master development scheme for the Metropolitan Area - SDAAM and the National scheme for territory development- SNAT) and be able to measure and follow locally the resulting planning actions. This perspective is adopted in this present article that aims to address the question of sustainability with regard to local urban development issues. In order to construct this model, two statements are considered :

- The purpose of our tool is to provide a framework for the assessment and implementation of sustainable urban planning. However, a review of the literature shows that it is difficult to find an operational definition of what is considered "sustainable." This difficulty could be overcome by using an applied approach, based on local issues, in order to offer a characterization of urban sustainability. According to this logic, an urban development/urban planning is sustainable if it could respond appropriately to the key issues expressed by local actors.
- The approach of the sustainability profile which combines both the shared diagnosis approach and the systemic one seems to be the most appropriate for the Algerian context, as it takes into account the complexity of urban territory. In addition, this

approach not only integrates the iterative character of practices regarding sustainable planning, but it also associates the local dimension and its intrinsic values into a participative approach.

3.2 An adapted sustainability framework to local stakes

The model developed in this present study proposes a general framework for urban planning in Algiers. It allows any territory to assess its own situation, define its goals in terms of sustainable planning and create appropriate mechanisms to achieve them. This profile is intended to provide guidance and support, to improve decision-making and action on sustainability. The tool is also designed to be adapted and expanded according to the particular situation of either city or municipality (issues, specific objectives and indicators). Consequently, the operational definition of the framework is based on three framing elements:

- The overall principles of sustainable development adopted by the SNAT and SDAAM as a guiding principle of territorial and urban planning in Algiers are: sustainability, equity, coherence and attractiveness. The model includes a tool of questioning, encompassing several main issues; these latter can give a concrete and operational translation to the conceptual framework defined by the strategy of urban and territorial development of Algiers. It should be noted here that these main issues correspond to the four types of environment: natural, urban, social and economic. In order to integrate concerns raised by the PDAU, it is necessary to take into account some priority themes of urban development.
- The approach based on local issues which considers the phases of urban planning, design and urban management after implementation. This will allow the assessment at three different periods within the process of planning operations (ex ante, mid-term and ex post).
- The local territory as a dynamic urban ecosystem encompassing natural, urban and socio–economic environments.

According to these considerations, the design of the framework will result from the combination of these interactive elements considering three steps: first, analyzing the strategic planning documents to identify key issues, then identifying thematic fields that hold challenges and finally modeling a system of assessment indicators.

Thus, after the analysis of planning documents, ten thematic fields were identified. They result from guidelines and key issues formulated at different scales. For each theme, indicators are associated. They interpret urban issues with either positive or negative impact. Some indicators describe the state of the environment on selected themes (energy and water consumption, transportation, green space ratio, etc.), whereas others reveal the potential for change as a response to deal with negative impacts such as environmental approach, conservation and economy of resources, management and recycling of waste, etc. This distribution is based on the PSR model (Pressure-State-Response), developed by the OECD (OECD, 2003). Most of indicators, adapted from the European referential INDI (Charlot-Valdieu & Outrequin, 2012) are either composite or elementary. Their total number is 50, among these, 13 belong to the natural environment, whereas 21 belong to the urban environment and the other 16 belong to the socio-economic dimension (see Table 1).

Table 1: Thematic fields and related indicators of sustainability framework

	Thematic fields	Indicators
Natural environment	Natural ressources *(guidelines n°1 of SNAT, fundamental question n°4 of PDAU, objective n°3 of SDAAM)*	1. Water consumption in the residential sector 2. Economy of drinking water 3. Economy of energy 4. Energy consumption 5. Heating system of dwellings (new and existing) 6. Use of renewable energies 7. Quality of sewerage network 8. Rainwater harvesting and management 9. Recycling of materials and products 10.Environmental approach and resource conservation
	Landscape *(Strategic ambition n°4 of PDAU)*	11. Landscape and visual quality 12. Public green spaces 13. Natural heritage and biodiversity
Urban environment	Urban space *(Guidelines n°2 and 4 of SNAT, objective n°4 of SDAAM, strategic ambition n°3 of PDAU)*	14. Urban Density 15. Street furniture and lighting 16. Public facilities (high quality environment HQE) 17. Architectural Heritage
	Housing /dwellings *(Fundamental question n°2 of PDAU)*	18. Quality of facades 19. Integration and consideration of the immediate environment 20. Proportion of adapted dwellings for the elderly and disabled 21. Diversity of housing (depending on the status, size and nature) 22. Proportion of unhealthy or unfit housing 23. Quality of semi-public spaces and common areas of housing
	Transport and mobility *(Guidelines n°3 of SNAT, Strategic ambition n°5 of PDAU)*	24. Roads (Site proper) 25. Travel by public transport 26. Quality of roads and pavements 27. Modes of soft mobility 28. Parking system
	Pollutions and nuisances *(Guidelines n°1 of SNAT, fundamental question n°6 of PDAU)*	29. Indoor air quality 30. NO_2 pollution and ozone (threshold of-health information) 31. Noise pollution 32. Part of polluting construction site 33. Household waste and selective collection 34. Waste management of construction sites and recycling
Social environment	Security and risk *(Guidelines n°1 of SNAT, fundamental question n°6 of PDAU)*	35. Urban Security 36. Road safety/security 37. Major natural and technological hazards
	Quality of social life *(Guidelines n°3 of SNAT, Principle n°2 of PDAU)*	38. Distribution of the population (age group, education, activities) 39. Facilities nearby and offers services 40. Loss and learning difficulties 41. Medical supply
	Participation *(strategic ambition n°7 of PDAU)*	42. Approaches to sustainable development and participation 43. Consultation with residents 44. Community activities 45. Social and solidarity economy
Economic environment	Economic attractiveness *(Guidelines n°3 of SNAT, fundamental question n°1 of PDAU)*	46. Unemployment rate 47. Accessibility and attractiveness of economic facilities 48. Local integration activities by economy 49. Economic events and fairs 50. Retail businesses

To illustrate this approach of the sustainability profile we took El Anasser district, located in the city of Algiers, as a case study. In the context of this application, we applied a sustainable development approach to this district. Our aim is to achieve both a sustainable development diagnosis and an assessment by indicators that will relate to all aspects of local life (environmental, socio-cultural and economic environments). This assessment will allow outline the state of the district ; the results will be used to identify challenges, to set out goals and thus to propose a strategic action plan.

4. The sustainability profile of El-Anasser district in Algiers

El Anasser district located in the municipality of Belouizdad has an area of 0.90 km^2 with 10,500 inhabitants. The disctrict is an immediate extension of the old center and has a coastline overlooking the Bay of Algiers. This central location and its new role as an emerging area of the capital city give it a particular interest. This is visible through successive urban policies that have marked its transformation process (Berezowska-Azzag, 2007).

4.1 Synthesis of diagnosis

El Annasser district has suffered many years from several socio-economic and environmental problems related both to quality of life and to local urban management (unhealthy, security, services, etc.). This district has many assets such as important land potential consisting of many industrial brownfields. El Anasser district is shaped by a planning and development objective following a policy which tends to favor certain activities (tertiary sector, commercial and recreational). This policy highlights a new image of a modern and attractive center. A renewal project has been initiated but it faces a specific socio-economic context and must support environmental impacts. Indeed, El Anasser territory reflects actual resources potential and actions that should be highlighted through a sustainable development project. It should be noted, however, that there is a gap between its current situation and future vocation of central district. Moreover, it appears that there is a lack of action means and a certain dispersion of organization and management.

This site is marked not only by a pressure on land, but also by high increasing demands for housing and community facilities. Requirements and expectations occur but operational difficulties exist as a result of both the heaviness of the decision-making processes and the conflicts of interests between different stakeholders. In addition, the advanced state of decay of the industrial equipment does not contribute to the development of a positive and attractive image of this district.

It should be noted however, that many facilities dedicated to specific modes of traffic (tram and metro) exist today, eventhough arrangements for soft mobility are lacking (walking and cycling). The quality of urban ambiance is rather bad on the roads supporting transit flows: noise, air pollution ; in addition, the lack of security in crossing these roads creates real barriers. The public park "*Jardin d'Essai*" adjacent to the neighborhood is not used to create functional and visual relationships. Cultural and recreational facilities are few and cannot represent the future attractive center at the city level. However, the nature of trade and transit attract, only on the outlying roads, a great number of people from nearby-municipalities and districts.

On the other side, the morphology of the building represents an enclosure conditioning interior fluidity and urban dynamics. The peripheral roads: Highway, penetrating road leading city, the

railway and the greenbelt of the Jardin d'Essai provide also physical barriers between the district and the city. The gap exists also between the site and its extension to the sea. This situation deprives the inhabitants from the opportunity to take full advantage of the existing potential.
However, the district is being transformed to change its previous dominant industrial character by a new urban renewal phase. These operations concerned primarily the *"Les abattoirs"* block. This latter concentrates a large number of urban wasteland. Recent operations have mainly affected the renovation and restructuring of the infrastructure. However, these operations (some not being completed yet) have caused multiple inconveniences to residents and users (congestion, noise, pollution by construction site dust, relocation, closure of shops, and rehousing of inhabitants often under-stress). The completed program, to date, includes the following projects : the buildings of the Court of Algiers and of the control and management center of the metro of Algiers, the tramway, the communications networks, the crossroads with the highway, the tunnel at the junction of the two major roads and the development of the multimodal station (subway, bus, tramway, and telpherage).

4.2 Assessment using indicators system

The aim of this assessment exercise is to carry out the district's sustainable development profile at three separate stages: first, at the beginning of the renewal operations (initial conditions: ex ante), then in the middle (at a certain stage of progress) and finally, applying an ex post evaluation (after completion of operations). Doing so, would allow both the assessment of the progress towards sustainability as well as the identification of particular aspects not supported by the urban renewal project. The model used applies qualitative judgments and quantitative measurements of selected indicators. These were grouped by thematic groups presenting the state of the district on a scale of sustainability also called performance scale.

Each indicator of the model has its value measured and estimated on the scale of sustainability. This requires the definition of a reference scale for the standardization of indicators and their representation in the same direction of change on a scale that ranges from 0 to 10. This standardization is called "axiological" it assigns 0 to the worst situation and 10 to the ideal one. Values are chosen according to the assessment context, the difficulty being in defining extreme values (Charlot-Valdieu & Outrequin, 2006). The model uses a method of aggregation of indicators, in order to carry out the profile by theme. We assign for each indicator a function to locate it on the scale of sustainability. The development of this function depends on the definition of "benchmarks" or "targets values" that shows wether or not an indicator is evolving towards sustainability. These targets values are empirical references based on the estimate of the "average" value and they are optimized realistically. In the event that a reference value is reached in a situation or a project, it is then appropriate to set new target-values as a reference threshold. We opt for a method of allocating values of sustainability indexes according to simplified functions.

A weighting is used to assign a weight to each indicator according to its relevance and importance in relation to the set goals. The standards values of indicators distributed on the same scale will be used to represent the profile of the district in the form of radar charts, three types of representations can be performed :

- Representation of the whole indicators on the radar chart.
- Representation of aggregated indicators by thematic field.
- Global representation of environmental, social and economic dimensions.

4.3 Results and discussions

The results are in the form of radar chart describing the state of urban aspects by theme (current profile), and providing easy reading that promotes communication between different actors. This representation shows also the expected improvements in the renewal project (tendantial profile). The nearest values towards the center of the radar chart indicate a failure of a particular aspect which needs to be improved by the project. Good values are located closer to the outer circle ; these values must be maintained (see Fig. 2). On the graph of the current profile, topics related to transport and mobility, safety and risk and quality of social life have a scores higher than "6", it is necessary to maintain their current effect. All the themes of sustainability which average range lies between "4" and "6" need improvement but their situation is not considered critical. However, five major thematic fields cause problem. These fields are the natural resources, the housing, the pollution and nuisances, the participation and the economic attractiveness. The priority actions must be oriented on these fields.

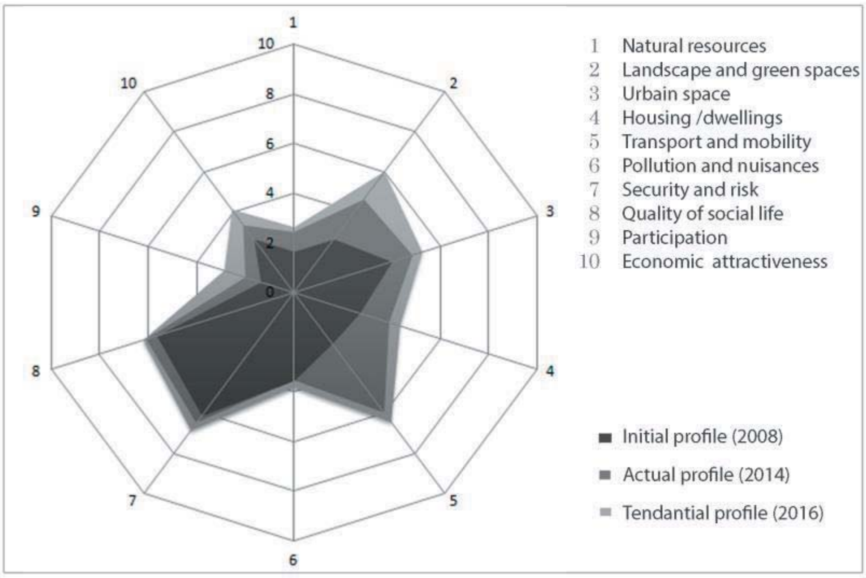

Fig. 2 Global urban sustainability profile of El Anasser district

Considering the overall objectives of sustainable development, the district appears to have an advantage with regard to public transport (underground and tramway) and to the accessibility, the socio-economic, functional, environmental and topological diversity and to the safety against major hazards. Nonetheless, this district has also a deficit in strengthening social ties (governance and participation), the management of resource and environmental quality (pollution, nuisance). This study has interpreted the reality of the district of El Anasser and highlighted its weaknesses and its strengths. The general appearance reflects several shortcomings in both the resources management (energy, water, materials...) and in the quality of the local environment (landscape, heritage, housing, sanitation, waste, noise, etc.). Nonetheless, this district fits the criteria of sustainability which seem to achieve the highest scores in the following fields: the mobility management, the diversity of functions, the level of education and access of the population to the public services and urban facilities. The results of this diagnosis identify key elements (major stakes) to which the development of the district may face in the short, medium and long term. This district must evolve to a higher level of performance for the thematic that have not been met ; the improvement must move towards a strong or very strong sustainability for some points. From the managerial point of view, the evolution relative to the effectiveness of public policy can be regarded as insufficient. Regarding some actions, particularly in terms of public transport, the effort is visible but quite often public action facing local issues did not have any positive impact. On one hand, this explains why the responses given by local decision-makers are not appropriate with the district reality and question on the other hand the effectiveness of the tools implemented.

5. Conclusion

The achievement of the evaluation with regard to sustainability is an important milestone. In this perspective and in view of achieving shared diagnosis, assessment should allow the definition of priority objectives that will express concretely the outline of sustainable urban project. The aim is to establish the conditions for a continuous improvement process that will lead stakeholders to consider all the stakes and to improve the relevance of their actions. This is a major challenge for local authorities to address the fundamental questions of success of investment, effectiveness of public policy and operational feasibility in terms of regulatory and management tools for assessment and monitoring.

The sustainability profile as a tool for measuring the local urban sustainability was particularly relevant through the application on the El Anasser district. It showed the potential uses of the system of shared diagnosis and evaluation indicator. However, this work represents only the first part of an iterative process to improve urban practices and produce measurable and comparable indicators for local sustainability in the Algerian context. Through its integrated assessment process, this tool will effectively provide guidance and improvements in decision–making process.

Adaptations of the tool are necessary for effective local application. The definition of reference values must arise from the application context for more consistency and more relevance. The results of this case study raise questions about the relevant indicators of our context and more specifically of the neighborhood scale, which is the subject of the assessment as well as on local reference standards to be defined. It is also a challenge for this tool to be adopted and used by local authorities, and to be linked with other sustainability initiatives being taken in supra-municipal levels such as the strategic project of planning and development of Algiers in 2030.

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Sustainability survey amongst architects in the German state of Baden Wurttemberg on the adaptation level of sustainability aspects in the real state sector

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Summary

In modern societies people spend most of their time in confined spaces. The work processes as well as the well-being of those who occupy these spaces are affected by both the design as well as the composition of rooms. To ensure the quality of living for future generations a responsible and sustainable interaction with resources is needed. According to estimates, 40% of the entire primary energy usage will be required for to operate the buildings. This shows that the real-estate industry must have an essential involvement in the development of sustainable strategies.
Sustainability highlights more than just energy balance and environmentally sustainability — at a basic level, sustainability also takes in economic and social aspects.
Thus, this discussion paper describes the level of adaptation of the three sustainability dimensions in analysing the adaptation levels among architects.To achieve meaningful results, about 1.200 architects in Baden-Wurttemberg were interviewed with the aid of a standardized online survey. As a result, coherences, differences and developments could be precisely captured.
The aspiration of this research work is to evaluate the existing practice of social sustainable buildings. The empirical analysis of the survey data shows that from the perspective of the architects, ecological and economical dimensions have a much higher adaption level over that of social sustainability. The architects who took part in the study also see the advantages of sustainable versus non-sustainable structures as well as the benefits of the ecological versus the economic.
In addition, the study investigates how the adaption level of social sustainability within the real estate sector can be increased and which barriers to adaptation could occur during this process from the architects' perspective.. In this regard, it should be noted that the funding of social sustainability, as well as an increased awareness of the real estate owners for social sustainability is play an important role. In the building sector this knowledge could contribute to a more in-depth understanding of the realization of sustainability, in particular of social sustainability.

Keywords: Sociology of architecture, social sustainability, sustainability, survey results

1. Introduction

In recent years an increasing trend can be observed in the real estate industry: sustainable real estate [1]. Nowadays there are many initiatives which support ecological and sustainable building. Passive-energy houses as well as energy-plus buildings aren't uncommon anymore. Today's demand for sustainability will increase not only due to an increasing ecological awareness, but also, for example, due to alarming global developments, like progressive climate change. This development will be accompanied by an increase in energy costs, which will lead to a 'green' trend within the real estate sector [2]. There are several national laws and regulations in Germany which concern ecological and sustainable building such as the Energieeinsparverordnung [2] [3]. The priority of sustainable analyses is not only the environmental compatibility of a building, — instead the economical and social aspects also play an equal role [4]. The adaption of normative outlines like sustainability within the sectors and the consequential changes of social practices are not always a sure-fire success and entail sociotechnical changes. Since the individual dimensions of sustainability are in a conflicted interrelation [5] it is possible that one dimension is adapted more than the other. Especially in the area of the real estate sector, a conflicted relation is reflected. Environmentally sustainable building and social sustainability do not go hand in hand. The requirement for an adequate thermal 'cosiness' can influence the energy efficiency of buildings because the cooling and heating creates a higher energetic effort [6]. Since the emergence of low-energy houses in the early 90's, a trend towards technical (over-) control of buildings has been observed. The modern energy-saving building technology, for example, takes care of the regulation of artificial light intensity or room temperature autonomously. Therefore, light switches or temperature consoles cannot be operated independently by the users. The increasingly centrally controlled technologization of buildings contradicts individual basic needs, such as independency or the pursuit of self-determination. Since the debate about sustainability has been dominated by the ecological perspective in Germany for a long time naturally the ecological dimension has adapted more than the social or economical dimension [7]. Within the real estate sector the indications are that the terminus of sustainability is synonymic to eco-friendliness.

Sustainability-oriented sectoral changes, on the one hand, depend on the adaptability of the professionals of one sector, and on the other hand, the state has become an important instigator of the implementation of mission statements due to its structure-building outputs [8]. The present article exclusively addresses the perspective of the professionals and examines the adaption level of the three sustainability dimensions. The adaptation level of an innovation is determined by the extent of integration within the social practices of a sector.

If social reality is understood as a societal construct, then the operating actors who undertake sustainability measures are not just objects but acting subjects who interpret standards and goals differently [9]. All requirements for sustainable buildings are consequently being construed and applied by the professionals. Thus, it is necessary to focus on the actors from the real estate sector in this analysis. The real estate sector encompasses a number of actors, products and services which are related to real estate. We are dealing with a complex field and this is not only due to the number of actor groups but also because of the number of specific submarkets. Hence, the analytical framework has to be confined. This paper examines architects as key actors. It is to be demonstrated that precisely these actors occupy a special position within in the real estate sector. A study of the real estate sector by use of a quantitative survey with the focus on architects who plan and implement the sustainability strategies has not been conducted until now. This article will close the demonstrated research gap. It is of utmost importance to explore the social sustainability dimension, which comprises the concerns and demands of users in greater depth. In this paper I will consider the question of the extent of the adaption level of the three sustainability dimensions — environmental, economic and social — from the perspective of the architects within the real estate sector. Furthermore, I examine the advantages and disadvantages of sustainable buildings over non-sustainable buildings. Additionally, it is still to be clarified in which measure the actors can increase the adaptation level of social sustainability. These research questions and the related research results are of utmost societal importance, due to the fact that such insights identify and create the basis for potential strategies for the integral sustainable development of user-oriented planning and building, which substantially targets the quality of life. Especially in the area of commercial, public and socially used real estate, architects play a major role because future occupiers are excluded from the conventional planning process of the building types. Thus, the architects must assess the present conditions and anticipate the future developments and demands of the occupiers while applying technical and social expertise. Therefore this paper will not refer to residential estates but to public, commercial and socially used real estates.

2. Methodology

For an adequate empirical study for this specific field of research, a limitation of the analytical framework is needed. This research step marks a typical problem for the empirical social research — from a theoretical viewpoint, often a large number of cases under investigation could be considered, however, these cannot be all taken into account due to research pragmatic circumstances. A possible counter strategy to stem the empirical investigation's inherent problem is to limit the number of cases. Thereby it is important to determine clearly recognizable and intersubjectively comprehensive criteria to prevent a random selection of investigation objects. In this paper the number of those polled has been reduced by a conscious selection of cases. In the empirical social research the selection strategy is the so-called principle of concentration. This includes the limitation to meaningful cases. Since from both a societal as well as an individual perspective the overall building environment is highly influenced by everyday actions, the individual actors who plan and construct the buildings are therefore of major importance.

By implementing sustainable developments within the real estate sector, architects play a central role because they are the ones who form the bridge between building contractors, participating engineers and future occupiers. Architects provide structure to our environment through realizing construction projects. Consequently, architects are not just experts for aesthetic and technical issues, but also explicit social designers of societal cohabitation. Thus, it is necessary to focus on these key players in the empirical analysis. For one, the scientific focus is on the architect as an expert, who is able to provide valid estimations about the practice of sustainable building. On the other hand, I consider the architect as an operating individual actor who actively implements sustainable building measures.

Since there are barely any scientific findings concerning these issues available, not to mention any quantitative data, I'm dealing with a research project which exploits a new field. Consequently, an autonomous inquiry of empirical data was made. For technical and practical reasons not all architects in Germany who participated in the planning of publicly and commercially used real estate, could have been questioned. Data privacy restrictions prevent the German architectural association from providing the addresses of all architects. An estimated 124.000 architects work in Germany today [10]. Hence, a further limitation is necessary. My goal was to limit the research unit to one state of the Federal Republic. The approach to the research field was made possible through the architectural association of Baden-Wurttemberg. Since affiliating with the chamber is mandatory for architects, the organization qualifies as a reliable source for the exact determination of the total number [11]. Since the inquiry of the data was online-based, architects who provide their email addresses on the architectural association's homepage could be polled. In order to prevent a bias regarding the publication of the email addresses, I additionally issued a call for participation on the Baden-Wurttemberg architectural association's homepage. It was therefore possible for architects who did not provide their email address publicly, to participate. Accordingly, this partial quantity of architects represents the selected entirety. The survey was conducted from December 2014 until March 2015.

Since the terminus of social sustainability is a complex and multi-layered term, I predetermined a definition for the polled architects. The benefit of this procedure is the comparability of the answers. Associated with that, an explicit predetermination of a definition can increase the validity, due to preventing a divergent comprehension of those polled opposite the inquirer's interpretation [12]. Greiff found a thorough but nonetheless precise definition. He defines social sustainability:

“The goal of sustainability is met, when throughout their whole durability, buildings are used by as many people as possible, support their social team spirit, enhance them culturally and do not reduce the livelihood of future generations due to the resulting encumbrances” [13]. Firstly, there is a need to clarify the significance of sustainable building in the daily work of the architects polled. By surveying the working practice,it can be determined if, and to what extent the issue of sustainability affects the practical routines of the architects, or whether it presents itself as a marginal phenomenon. This aim is guided by the following questions: *How significant was the issue of sustainable building in your daily work within the past 12 months?* The respondent can choose between *very low* and *very high significance* on a five-tier scale.

Secondly, it has to be considerd what extent ecological, economic and social sustainability aspects are included within the real estate sector. By estimating the adaptation level of the three sustainability dimensions, the goal is not to analyze the individual attitudes or practices, but to develop an opinion on the respondent’s observed practice routines within the real estate sector. The respective item is as follows: The fundamental understanding of sustainability of the three dimensions includes the ecological, the economical and the social dimension. *How strongly do you think the three dimensions are being considered on a national level?* The respondents can select between none or very strong consideration on a seven-tier scale. Self-reinforcing effects are important factors that benefit the adaption of innovative impulses within the sector. Legitimizing normative concepts towards an adaption object count as self-reinforcing effects for stabilizing social practices. These factors can have a consolidating effect and are able to increase or complicate the adaptation ability within a sector [14]. Depending on the personal preference of those polled, different significance levels can be attributed to each dimension. Through this one can determine perceived advantages, in the sense of adaptive expectations, of sustainable buildings which represents an important hint for the legitimizing general outlines. The adaptive expectations are examined through the following item: *What are the THREE most important advantages of sustainable buildings versus non-sustainable buildings?* The respondents have the opportunity to select three out of nine sustainability aspects, as well as adding advantages to the empty response fields individually. Three of the given advantages can be matched to each sustainability dimension:

<u>Ecological sustainability dimension:</u>

- Using renewable energy sources
- Lower level of environmental pollution load
- Energy efficiency

<u>Economic sustainability dimension:</u>

- Higher salability / tenancy rate
- Lower additional costs
- Higher financial value of the buildings

<u>Social sustainability dimension:</u>

- Integration through open access for users from outside
- Higher health rate of the occupiers
- Higher comfort for the occupiers

Through an additional question, the importance of both, certain actors and also measures for promoting social sustainability within the real estate sector, a direct relation to specific proposals can be created. Thus it is possible to gather recommendations for action for increasing the adaptation level of the social sustainability within the real estate sector. The focus lies on the state’s incentives and regulations. Based on a study of the *Real Estate Management Institute,* possible criteria, which could prevent the implementation of social sustainability were identified, several modifications were made and further measures were implemented. The item reads as follows: *How important are actors and measures for the advancement of social sustainability within the real estate sector in Germany?* Following measures and actors were stated:

- legal requirements (regulations)
- financial subsidies for socially sustainable buildings
- owners/ landlord
- tenants
- project developers
- investors

The respondents could choose from a five-tier scale whether they considered respective issues as *very important* or *not important at all.* After explicating the methodical process of the study, we can focus on the results of the survey.

3. Results

The homepage data from the architectural associationis evaluated together with the data from the personalized and online-based survey. For this survey we are dealing with two identical questionnaires and to ensure validity of the data the procedure was verified with the help of statistical t-tests. The average value of the inquiry is similar and can be confirmed with an error margin of 5%. Since there is not a complete list regarding the entire basis available, it is impossible to conduct an accidental sampling procedure. Consequently, the presented results cannot be generalized. Accordingly, it is not possible to conduct inference-statistical procedures [15]. Based on 18.896 registered architects in the architectural association of Baden-Wurttemberg 5.580 email addresses can be identified. This partial population represents the gross initial sample. After subtracting relevant sample loss, the net sample results in a potential field of 4.933. After excluding cases of missing values the sample consists of 1.292 cases which leads to a realized response rate of approximately 26.2%.

3.1 Importance of sustainable building in everyday professional life

The results of the survey indicate that during the last 12 months, the issue of sustainability achieved a higher importance in the daily work of the architects. Only 4.4% of the polled architects state that the issue has no importance at all. However, 12.2% of the architects state that the issue of sustainability is very important in their everyday professional life.

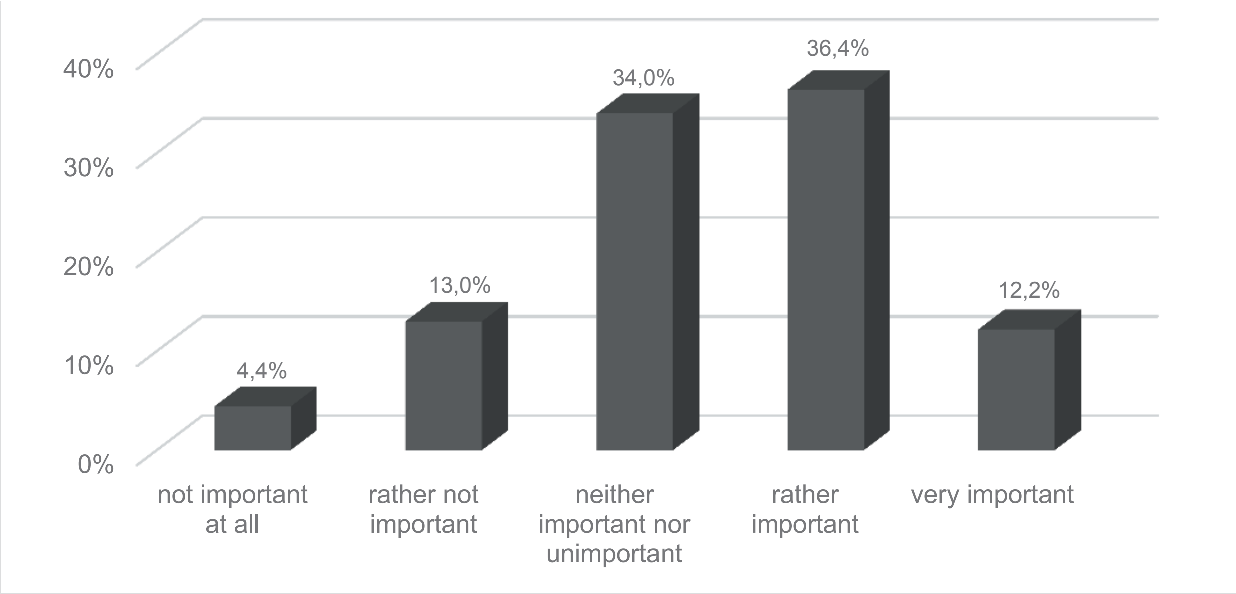


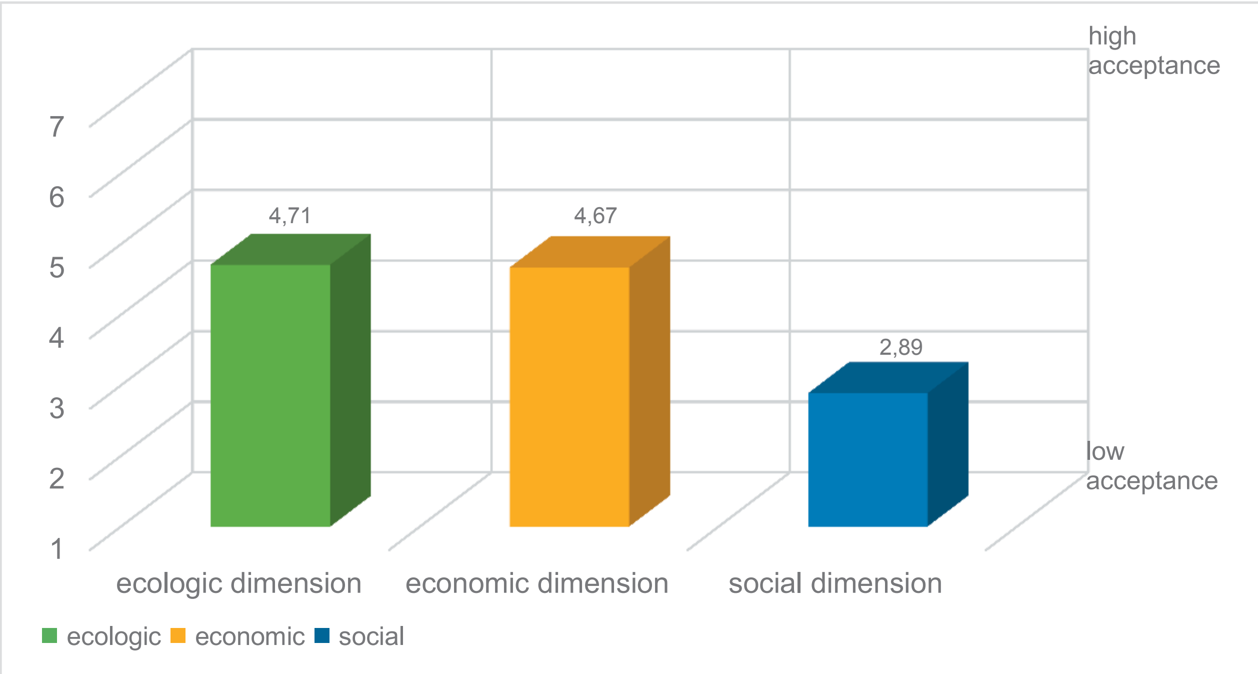
Figure 1: Importance of sustainable building in everyday professional life

Source: own data; n: 1225

The majority of 36.4% stated that sustainability is rather important for them. The evaluation shows that most of the architects are dealing with sustainable construction projects and that sustainability plays a substantial part within the real estate sector.

3.2 Perceived adaptation level of the three sustainability dimensions

The next step is to determine the respective adaptation level of the three sustainability components separately. Remember: The architects provide an estimate as experts in the field of real estate; they did not inform us about their personal practical routines. The described distribution of the data concerning the architect's perceived adaptation level of the ecological, economic and social components within the real estate sector shows, that the social dimension clearly exhibits a lower adaptation level.



Figuur 2: Perceived adaptation level of the three sustainability dimensions

Source: own data; ecological dimension n: 1151, economic dimension n: 1155, social dimension n: 1156

According to the assessment of the architects the ecological sustainability component exhibits the highest adaptation level with an average value of 4.71. Also, in comparison, the economic dimension is considered substantial as well with an average value of 4.67. The social dimension presents the lowest value with 2.89.

3.3 Advantages of sustainable buildings

The described evaluation of the question concerning the three most important advantages follows next. Here, I examine the architect's legitimizing general outline regarding the perceived advantages of sustainable buildings within a sector. These present important evidence for the self-enforcing effects.

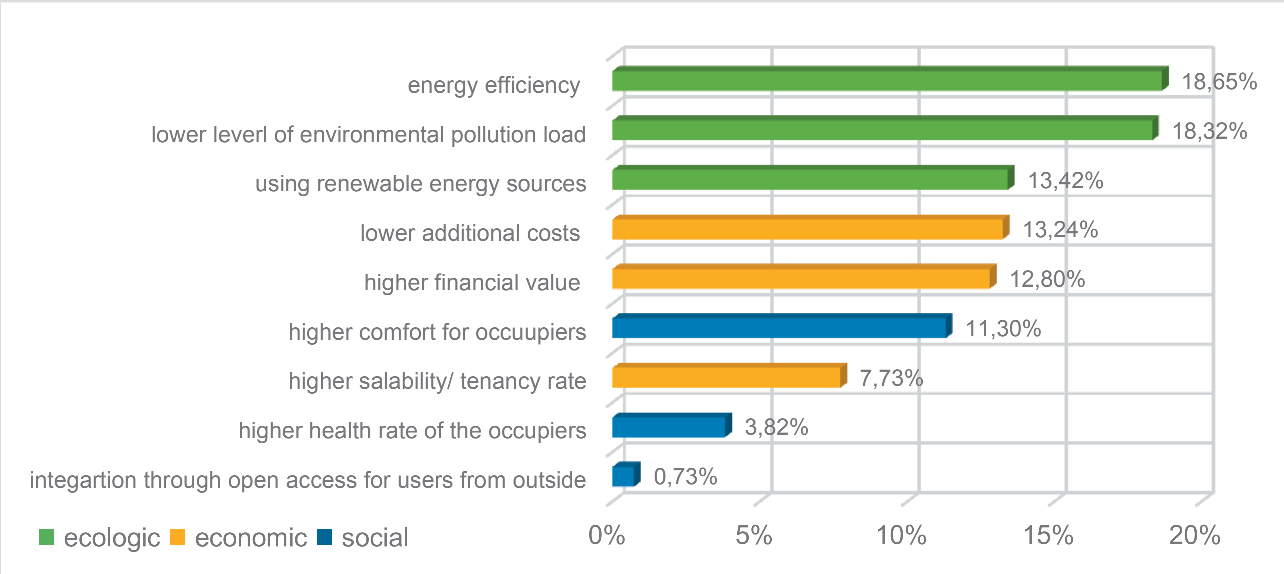


Figure 3: Advantages of sustainable buildings versus non-sustainable buildings

Source: own data, n: 1210

By observing the distribution of all valid indications in terms of the three most important advantages of sustainable buildings versus non sustainable buildings, architects predominantly name ecological aspects. The three most common mentioned advantages are ascribed to the ecological sustainability component. 50.3% of the perceived advantages are attributed to the ecological dimension. In total, 33.8% of all valid answers are attributed to the economic sustainability dimension. From the view of the interviewed architects, lower side costs/utilities and a higher building value are the fourth and fifth most important advantages of sustainable building. Not until the sixth place with an overall percentage of 11.3% comes the dimension relating to more comfort for the users, thus referring to the first mention of an aspect of social sustainability dimension. The subordinate status of socially sustainable advantages is underlined due to the positioning of the other two advantages in the second to last and last place. Altogether only 15.8% of the responses refer to socially sustainable advantages. There is a dominance of ecological and economic advantages, whereas advantages of social sustainability are considered less important. This affects the self-reinforcement of ecological and economical structures within the real estate sector, due to attributing them with a higher legitimacy. In comparison, this shows that there is a lower adaptation potential for social sustainability aspects.

3.4 Importance of the actors and measures

By studying the importance of certain actors and measures for promoting social sustainability within the real estate sector, direct application relevance can be established. This, in turn, is important for concrete recommendations for the promotion of social sustainability within the real estate sector. Regarding the responses to the point under which actors and measures and the importance of promoting social sustainability within the real estate sector, it can be deduced that arithmetic means are high throughout and thus can be attributed to the semantic category important. Strikingly, the tenants are tangentially awarded the status of lower significance and are nearing the semantic category of neither important nor unimportant.

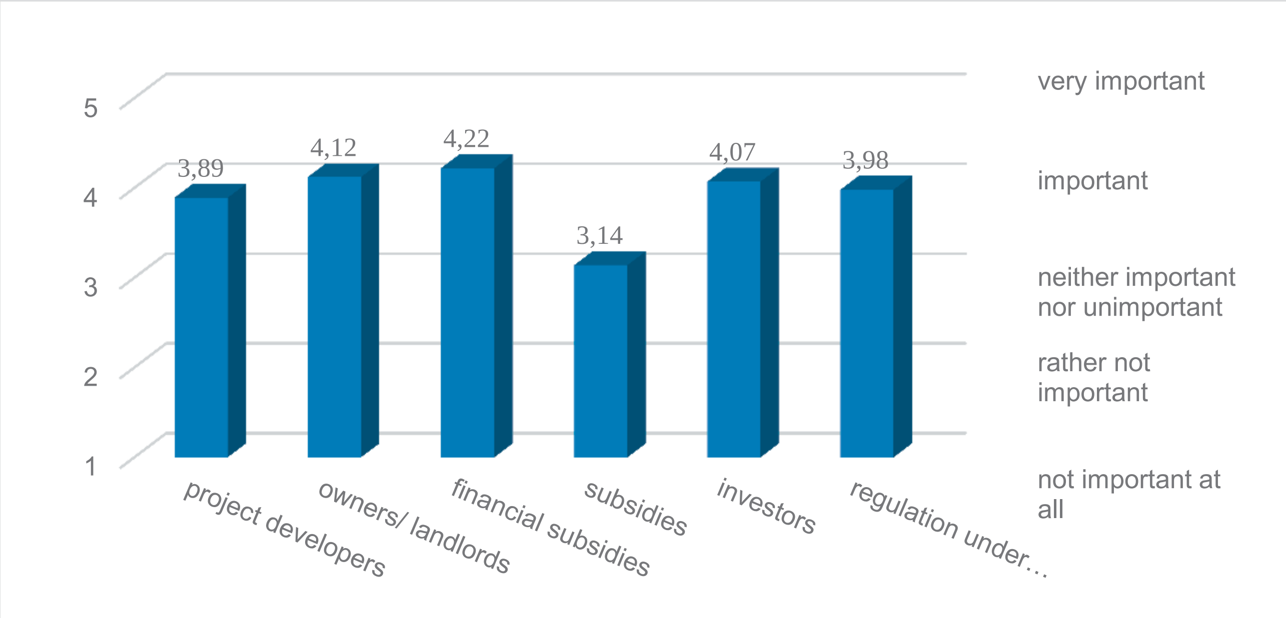


Figure 4: Importance of actors and measures for the support of social sustainability

Source: own data, n: 964

The highest relevance is attributed to financial subventions (can also use subsidies) with an arithmetic mean of 4.22, closely followed by the actors groups of landlord/tenant with an arithmetic mean of 4.12 and the investors with an average value of 4.07. The financial support of socially sustainable measures represents a direct connection to allocative resources, which, in reference, can create incentive structures within a sector. Fiscal incentives, as well as state regulations which can be evaluated as 3.98 arithmetically, have a central position from a regulatory perspective, if self-regulating market mechanisms preventing the failure of the market due to too little consideration of socially sustainable standards, are missing [2].

4. Discussion

The inquiry is limited to approaching the ideal of generally applicable statements by means of one representative selection of the cases examined. Nevertheless, this analysis can be an important contribution to an as yet little covered research field. Due to the technical and practical feasibility, it is impossible to examine all of the real estate actors in regard to the adaptation level of social sustainability by use of a quantitative inquiry within a scientific study. Through applying the principle of concentration and the chosen approach it is possible to examine a central group of actors within the sector. Other research intentions should follow this approach and examine the real estate sector using quantitative methods. One structural disadvantage of any online-survey is that only people with an email address or with internet access can be questioned [16]. In regard to the examined subpopulation, however, it can be assume that most of the architects have internet access and an email address due to their profession. To further classify the results from the analysis regarding the high relevancy of investors and landlords it can be advantageous to take a brief look at the "vicious circle of real estate” (s. Fig 5).

The essence of this vicious circleis the relegation of responsibility for the realization of sustainable methods to other actors in the real estate sector. The graph represents the viewpoint of the involved actors for the real estate sector and relies on the market’s inherent supply — and demand situation. The group of investors includes both natural persons in the form of (private) donors, as

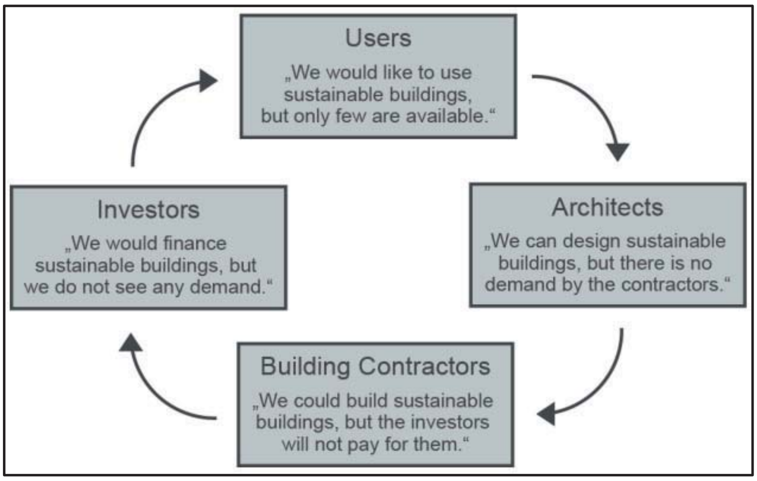


Figure 5: vicious circle [2]

well as legal entities that invest client funds in real estate as financial intermediaries, professionally.

Since approximately 92% of the total capital volume within the European real estate market is in the hands of professional investment firms, actors for the successful realization of fully sustainable buildings are especially crucial [2]. Analysis of the data shows that according to the surveyed architects one can find clear empirical evidence of the vicious circle. A successful implementation of the sustainability principle requires an equivalent consideration of the dimensions on the one hand, and a transparent handling of each dimension’s target conflict on the other [17]. The idea of transparency can only be achieved through an intact communication and an intensive exchange of the actors involved. Therefore one must try to break the vicious circle of accusation while increasing the exchange between the actors in order to generate optimized solutions regarding an equivalent adaption of the sustainability principle.

5. Conclusion

The results of this study show that the issue of sustainable building is of high importance for architects in their everyday working lives. According to the architects questioned, the respective dimension of sustainable building is viewed differently at the national level. The ecological and economic sustainability dimensions point to a similarly high level of adaption, whereas the social sustainability dimension is attributed to a lower level of adaption. In respect to the normative general outline of the architects, it may be stated that first of all ecological advantages can be noticed by sustainable real estate. Furthermore, economic benefits are considered more important than social sustainability aspects. These results indicated that the ecological and moreover the economic sustainability dimension are being adapted proactively from the architects questioned due to attributing a greater benefit to these components. Furthermore, a higher importance of the ecological and economic sustainability dimension opposing the social sustainability dimension can have a stabilizing self-strengthening effect.

Due to the difficult relationship of the sustainability dimensions, a proactive adaption of the social sustainability can be made difficult within the real estate sector. The practice of building must be rethought with respect to its appropriateness in the light of the presented survey results showing the low adaption level of the social sustainability. Only through critical reflection of established practices can unwanted side effects be considered and thus prevented. A higher adaption level of social sustainability cannot be achieved through the adaption of the regulative framework alone, but also requires a sectoral problem perception from the architects and other involved professionals. Although the empirical results presented here emerge as a clear picture in favor of environmental and economic components, while the social sustainability only plays a minor role in comparison, a potential change in the real estate sector towards more social sustainability should not be ruled out. Within the next 20 years about 50% of existing building stock in Germany is subject to redevelopment. At the same time there will be many new construction projects [18]. Knowledge is a fundamental element for the application of concrete social sustainability strategies within a sector. And knowledge is created through communication. But knowledge alone does not create change even though an elemental premise to initiate change is created. In particular it is the ability to assess the efficacy of intended changes which plays a central role in the transformation processes within sectors [19].

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Sustainable Housing Design.
Integrating technical and housing quality aspects of sustainable architecture in civil engineering education.

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Summary

An integrated design approach to sustainable architecture is outlined that combines concerns for zero energy building, good indoor climate and adequate constructions, private and public outdoor space, housing, urban and architectural quality. The educational framework, curriculum and integrated design methods are preconditions for optimizing a design process where technical criteria, functional concerns and housing quality are addressed from the initial phases. The outcome shows that integrated design further solutions where sustainable urban forms of settlement can be highly energy efficient while also attractive from a user perspective.

Key words: Sustainable architecture, integrated design, zero-energy-housing, dense urban living.

1. Intro

When designing sustainable housing, energy optimization and subsequently satisfactory indoor climates are central issues that need to be incorporated from early design phases if to reach a coherent design. It might also be argued that the energy consumption of contemporary buildings only plays a relatively minor role compared to energy consumption related to private transportation of the occupants of buildings. Research points towards high urban density if to reduce the need for private transportation. But Danish families prefer to live in detached houses situated in less dense suburbia to achieve sun, fresh air and green space. Thus, if one wants to realistically solve the issue of sustainable housing design one must address the intertwined aspects of building construction, urban density and neighborhood qualities which calls for an interdisciplinary design approach. This paper tells of a thoroughly tested civil engineering education program at university master level dealing with the complex issue of combining zero energy building with dense urban living for children families.

2. Educational traditions

In European architectural education two major traditions can be identified: One is the beaux art-tradition where architecture is taught and trained at art academies favoring artistic approaches and emphasizing the aesthetic aspects of architecture. The Parisian Académie des Beaux-Arts

opened in 1648 [1]; the École Polytechnique [2] followed in 1794 paving the path for an educational split between the aesthetic and technical aspects of building design and the split between architects and engineers that is now a common reality across Europe. The second tradition might be called the technical tradition. Here the architectural education takes place typically at technical faculties emphasizing technical aspects of design. Unlike the beaux art-kind that favor studio work the technical tradition gives weight to hard knowledge, lectures and exercises and are often focused on finding technical solutions for fixed designs leaving little space for freer form findings.
Both Danish architect schools opening respectively 1754 and 1965 clearly belong to the beaux art-tradition. In 1997 a new architectural program was introduced at the technical faculty at Aalborg University with the aim of educating civil engineers specializing in architecture and design, A&D. Aalborg University is in general characterized by solution-oriented research, problem-based learning (PBL), project work and group work. The new architectural education was aiming for integrated design consciously placing itself right between the artistic and the technical tradition. Though ‘cross disciplinary’ and ‘interdisciplinary’ are celebrated terms in contemporary project rhetoric, integrated design is harder to practice than it seems at first sight: The split between technical and artistic approaches is also a split between different views upon the world and reality, research and design methods. Where technical research and education are clinging to objective truths, deductive processes of inquiry and cause-and-effect explanations [3], artistic approaches are often intuitive. When Baumgarten introduced the term *aesthetic* in 1735 [4] drawing attention to the sense of beauty he did so in a European reality increasingly influenced by nature science, logic and rationalist philosophy. And for centuries artists and art institutions have defined themselves in opposition to the rationalist paradigm while claiming subjectivity, feelings and sensuous experience. Both the engineering and architectural professions are nowadays strong carriers of collective mindsets. An in-between integrated-design position is up against strong traditions and the individual designer must overcome the institutionalized cleavage of common building design.

3. Educational framework

3.1 The bachelor

The master programs rely heavily on students having gained a strong foundation through their bachelor studies. The A&D bachelor includes six semesters [5]. Each semester consists of three 5 ECTS courses and one 15 ECTS project module. The courses have the format of lectures and exercises while the project module is studio work. Courses are scheduled early in the semester providing knowledge and skills for the project. The three courses are in most cases respectively a technical course, an ‘integrated design’ course and a course on architectural and urban theory and history. The integrated design-course introduces digital tools that are used for exercises or sketching of minor designs where the teachings of the technical course are integrated in an architectural design. All courses are examined individually while all projects are done in groups of four to six people and evaluated through group exams. Being the first education of its kind in Denmark, the teachings have been carried out mainly by a mix of traditionally trained architects and engineers, but in later years A&D candidates have been enrolled as assistant and associate professors, themselves having an integrated background. The bachelor teachings are in Danish.

3.2 The architectural master

The master program runs in English and international students from different, mostly European schools are admitted based on an individual assessment that includes both technical and design

skills. The first two semesters on the A&D master in architecture [6] focuses on respectively tectonic architecture and sustainable architecture and there is no formal progression between the two. Each of them consists of two five ECTS courses and a 20 ECTS project module that due to its length gives time for several iterations through the design process. As the students typically spend their third semester in internships and their forth on doing their master thesis, the tectonic and sustainable semesters are central in the university shaping of the students' professional profile.
The semester focusing on Sustainable Architecture starts with two five ECTS-courses. The first is entitled Zero Energy Building, and 'the aim of the course is to enable students in a professional way to develop and document Zero Energy Buildings using both passive and active energy technologies' [7]. Among the learning goals are the skill to be able 'to analyze, simulate and apply passive energy technologies in buildings' and the competence to 'use a professional and interdisciplinary approach to the design of zero energy building'. In short this is the course where the students are provided the necessary technical tools to ensure zero energy use and a comfortable indoor climate in both new and old buildings.
The second course is entitled Integrated Design of Sustainable Architecture, and the aim of this course is 'to enable the student to acquire knowledge of technical, functional and aesthetic aspects of and approaches to sustainable architecture, to acquire knowledge of integrated design concepts and become skilled in analyzing and comparing such approaches and concepts with regard to user needs' [8]. This course has a broader and more conceptual and pluralistic profile with the learning goals of acquiring knowledge of 'different approaches to sustainable architecture' and the skill of being able to 'analyze and reflect upon the integration of climatic, technical, spatial, social, functional, aesthetic and logistic needs of a specific client and/or user group'. Both courses are examined individually. They provide knowledge, skills and practical tools for the 20 ECTS main project, Sustainable Architecture, which are worked out in groups of five persons.

4. The project: A mixed-use zero-energy housing complex

4.1 Curriculum

Through the project entitled Sustainable Architecture the students must aim to fulfill the learning goals outlined in the Curriculum [9]:

Objective:
The aim of this project is to develop preliminary building design for a zero-energy building using advanced integrated design process methodology. Technical, spatial, social, functional, logistical as well as aesthetic problems must be solved in the integrated building design.
Students who complete the module:

Knowledge
Must have knowledge of advanced integrated design
Must have knowledge of different strategies in the field of sustainable architecture
Must have knowledge of passive energy technologies in relation to indoor environment

Skills
Must be able to elaborate the building design through the advanced use of the integrated design process
Must be able to integrate technical solutions in relation to energy and climate with respect to the performance of the building

Must be able to evaluate the technical solutions for the building
Must be able to choose, implement and combine strategies for the use of passive as well as active energy technologies
Must be able to model and design zero-energy buildings with sustainable architectural qualities
Must be able to devise solutions which includes social, technical and environmental aspects
Must be able to identify and target their design to the defined user group and their demands and well-being in the building

Competencies
Can develop an integrated building proposal that fulfills all predefined architectural, functional and technical design criteria and target values
Can communicate proper terminology in oral, written and graphical communication and documentation of problems and solutions in the integrated design of buildings and building services
Can discuss and reflect on potentials and limitations in integrated building energy design'.

4.1.1 Following the curriculum

Integrated design is a key word in the curriculum, and the architectural aspects that are to be integrated are both technical (passive and active technologies, reaching zero-energy), functional (targeting the design for a specific user group, their demands and well-being) and aesthetical (architectural quality, local environment, user's well-being), thus reflecting the Vitruvian triangle laying out how architectural form should be derived by the triple concern for beauty, usefulness and strength [10]. The learning goals; knowledge, skills and competencies may be achieved in a multitude of ways through many sorts of architectural design and for sites in any part of the world. The students are in principle free to define their own project but the vast majority of students choose to do the project that is proposed in the semester description, which in reality acts as a detailed plan for the semester activities.

4.2 Method

In order to carry through the project the students are recommended to use the Integrated Design Process-method as described by Mary-Ann Knudstrup, that has been developed especially for the A&D architectural program and its intention of combining architectural and engineering skills in design work where 'artistic learning, the creation of ideas, and an ability to see new possibilities and be creative become just as important parameters as the ability to identify problems and suggest a rational solution' [11]. The IDP-method operates with five phases:

1. Problem formulation / project idea.
2. Analysis Phase. Analysis of site, urban development plans, user profile, chart of functions, principles of energy consumption, indoor environment and construction. Aim and program.
3. Sketching Phase. Through the sketching process architectural ideas are linked to principles of construction, energy consumption and indoor environment as well as the functional demands to the new building.
4. Synthesis Phase. Architectural and functional qualities, the construction and demands for energy consumption and indoor environment flow together, and more qualities may be added. A new building has been created.
5. Presentation Phase. The final project is presented in a report, drawings, a cardboard model and IT-visualization.

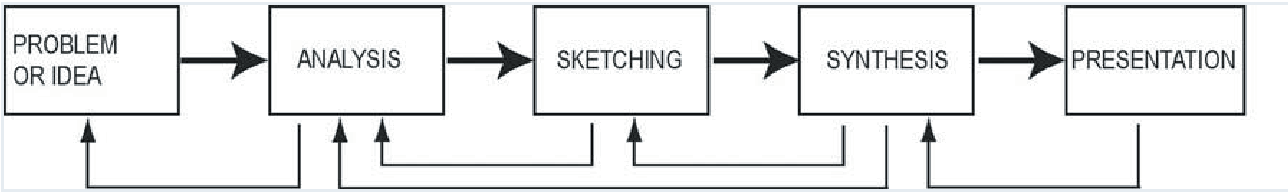

Fig.1. IDP-method as described by Mary-Ann Knudstrup.

Ideally the phases follow in chronological order, but students may realize for instance during sketching that more analyzing is needed which explains the 'loops' – the arrows pointing backwards to earlier phases. Especially in the sketching phase many designs must be tried and iterations must occur. The iterations continue into the synthesis face until a final solution is settled.
In the conventional way of building in Denmark the architect hands the project over to the engineer when the schematic design of the building is pretty much finished which means that the engineer assumes a reactive role in the design process instead of a proactive role which is required in an interdisciplinary approach to design [12]. The IDP-method by Knudstrup takes an architectural starting point but integrating architectural and engineering aspects as one profession.

4.3 Framing the project

4.3.1 Educational intentions

On the master projects with a high level of complexity must be expected handling technical, spatial, social, functional, logistical and aesthetic problems, as the curriculum says. It should be noticed that economy and construction management is not part of the curriculum as this is taught on the next semester, and that sustainable certification systems are only a minor part of the semester course teachings, still in an early phase of being implemented both in Danish practice and education. Even with these limitations the scope of the curriculum is very broad.
It has been the wish of the project responsible who is also the author of this paper, to frame a project that carry realistic architectural and engineering everyday challenges while at the same time opening for visionary responses; also to shed light on some of those dark areas that seem to remain in the scientific landscape after the different sciences and professions has pointed their attention their way to their favorite fields: Urban designers tend to have sociological approaches not realizing the physical resource consequences. Traditional engineers may have a technical approach not realizing the consequences for the quality of human life. And artistic architects may disregard environmental concerns and simple human functions in favor of stylish solutions.
In the Danish building sector sustainable concerns have been and are very focused on reducing the need for room heating, a heritage that dates back to the 1970'ies oil crises where room heating accounted for a large part of the national energy consumption. Due to building regulations with higher demands for insulation, room heating now plays a relatively minor role while the use of all sorts of electrical equipment are going up along with motorized traffic: In a new-built suburban house an average family will use more than twice as much fuel for running their cars than for running their house [13]. The need for private transportation in average decreases as the urban density goes up. On the other hand very dense settlements may cause shadow problems reducing the potentials of passive solar and increasing the risk of urban heat islands and cities with major cooling demands. A study of sustainable settlements based on aspects of transportation, urban heat islands and passive and active solar points to an optimal urban density between 50 and 150 % [14]. Terraced housing may have a density of 50 %.
The question is if a high density is appealing not only to trade and institutions but also to people when they look for a place to live. Students and young people may find many benefits from urban

life but in Denmark there is a strong tendency for young families to look for suburban settlement when they have children [15]. And once people move out of the city and into the wide-spread suburbs there is a tendency that they will stay there also after the children have left home. Several reasons for choosing suburbia have been identified and some of these reasons include the obvious physical qualities of access of sun, private gardens etc. In a sustainable perspective it is of utmost interest if such suburban qualities can be established also in a denser urban context.

4.3.1 Design brief

The sustainable semester project sets the following demands: 'The purpose is to design new energy and climate optimized dwellings with innovative housing qualities on [a specified site]. During the Project Module a housing complex is sketched, with an average height of no less than three stores and a building percent (floor-area-ratio) between 100 and 200 %. Up to 20% of the floor area may contain other functions such as shops, offices or kindergarten. Within the complex at least two units must be designed, one of which is a dwelling with a gross area of maximum 115 m2 including access area (such as staircases, access galleries etc.) for a family with children, including at least three bedrooms, and directly connected with an outdoor area of at least 20 m2. The other unit can be another dwelling or can contain non-dwelling functions. Regarding energy consumption, the units as well as the whole complex must hold zero energy-standard' [16].

The reason for suggesting mixed-use hosing is two-fold: An important reason for the residents in the dense city to have only minor needs for transportation is its mixed-use character of containing both housing, trade, jobs and institutions so ideally all daily destinations can be reached by foot, bike or public transportation. The second reason is that housing units may benefit from passive solar, while offices, shops etc. may thermally function better without direct sunlight. A mixed-use design may benefit from including both types of function. Other user groups than children families may be included and it is up to the students to analyze and argue why and which specific users should be integrated just as it is up to the students to argue if and which non-dwelling functions should be part of the building complex. In both cases the answers will depend on the character and context of the specific building site. Concerning 'suburban' qualities the brief contains one specific demand: That of an outdoor area directly connected to the individual housing unit. It is up to the students to argue if other 'suburban' qualities should be implemented.

The project task is deliberately Vitruvian in its triple demand for 'beauty, usefulness and strength'. In this case 'strength' is not so much about bearing constructions and durability but rather the environmental strength of obtaining zero energy and good indoor climate. Usefulness is an obvious concern when addressing social housing and the many functions that must find room within limited space. Beauty covers the sensuous qualities of a housing complex adjusted to its context; qualities of visual, audio and tactile character.

4.4 Process

4.4.1 Introduction

The studio project, Sustainable Architecture is introduced at the beginning of the semester, so the students get an idea of the overall intentions of the semester and the relevance of the course teachings. When the courses are done the students divide themselves into groups of five and initiate the studio work. All groups are appointed both a main supervisor, who has an architectural background, and a co-supervisor, who has an engineering background. The groups have meetings with supervisors on a weekly basis.

4.4.2 Analyzing

As the project responsible teacher have come up with the problem formulation which is defined as the first phase according to the IDP-method, the students now enter the second phase which is analyzing and encompasses site, user groups, technical and aesthetic intentions. Being master students they have great freedom to choose the approaches and sub-methods they find relevant.
The site is typically analyzed through Kevin Lynch-mapping [17], Gordon Cullen's serial visions [18] and climatic mapping including sun, shadows and local wind conditions. The students also register the functions of the area, such as residential, commercial or cultural buildings, and the traffic including trains, busses, cars, noise and air pollution, bicycle and pedestrian routes. Concerning user groups the students look into the preferences of children families and why they wish to settle where, but also reflects on which other user groups might be integrated with the children families, reflecting on the implications of social sustainability. The analyses span from hard knowledge including demographic statistics and scientific reports to the students own childhood recollections.
Some technical standards such as zero energy level are defined in the design brief, but the students may add more aspects such as life cycle analyzing (LCA) when choosing building materials. In both cases the students need to reflect on how the technical demands will influence the architecture, and how the architecture might help to obtain the wished for technical levels.
The part of the analyzing that is most difficult to grasp is the aesthetic intentions. While site and technical demands are themes with loads of hard facts, aesthetic qualities are harder to define. Students map local architecture to gain contextual understanding; reflect on user demands (e.g. urban greenery) and add their own aesthetic preferences obtained through years of studies.
The analyses are condenced in a 30-50 page program that concludes with a set of design criteria that works as guidelines for the sketching phase. The analysis phase lasts two-three weeks.

4.4.3 Sketching

Having been reading and writing the architectural students are by now eager to design. This is done through pencil drawings, model building with foam and cardboard, and computer work that initiates with simple form making and goes through different stages of parametric modeling where e.g. sun paths, daylight levels, passive solar, energy balance and indoor climate are allowed to influence the design. The early part of the sketching phase is supported by three two-day workshops entitled respectively: 'Climate, volume, orientation and access', where the students make proposals for master plans seing the housing complex from outside; 'Daylight and dwellings', where the students make proposals for housing units seing the architecture from inside focusing on indoor space and light; and 'Materials' focusing on building materials both technically and aesthetically. As computer work tends to dominate the sketching phase, the students are encouraged to work through analogue modeling in these workshops. Halfway through the sketching phase a midway critique is organized. At this stage the students must present one or two concepts that clearly communicate an architectural idea based on the design criteria.

4.4.4 Synthesis

Having settled for a conceptual design now the time has come to wove everything together and make ends meet; to adjust, make fit, calculate and optimize so that all technical, socio-functional and aesthetic criteria are met. At this stage it becomes clear which groups have had an integrated design approach through the earlier phases. If the analyzing has been thorough and the sketching has included also the energy and indoor technical criteria this phase may be a relief, though still a hectic phase, where everything falls into place. If the students have disregarded central aspects of sustainable architecture design it may be a confusing phase of damage control.

4.4.5 Presentation

The students then work on presenting their architectural design in a both informative and appealing way including plans, sections, facades, three-dimensional renderings of both interior and exterior and diagrams showing the sustainable quantitative performance of the buildings. A report is made showing program (concluding the analysis phase), process (reflecting on the total design process including analyzing, sketching and synthesizing) and presentation, and the report is uploaded and handed in in hard copy. Between the report submission and the examination the students additionally work on physical models in different scales showing results from urban context over buildings to constructional detailing.

Fig.2 Katrine Ravn Møller et al (2014): Zero energy-housing with roof terraces, in central Aalborg.

5. Discussion

Every spring 12-15 mixed-use zero-energy housing projects are designed according to the above mentioned curricula and project module description. The vast majority of students in the five-person groups pass but of course they perform differently, some being very good at calculations, others having a good sense of occupant's needs and a few students mastering every aspect of architectural design. The group work and mixing of talents usually ensures that a good all-round level is achieved concerning project quality. Some tendencies are clear:
Students fulfill the energy goals: They housing units reach the Danish low energy 2020 standard, which is 25 kWh/m2/year including heating, hot water, ventilation and cooling, by passive means. This is achieved by designing relative (but not necessarily very) compact building volumes, and by having 35-40 cm insulation in the outer walls. The thick layer of insulation often causes the students to choose light outer wall construction to maintain a slim outer wall, while instead having heavy, bearing constructions for inner walls and decks that may also provide thermal storage. The dimensioning and orientation of windows are important. A southerly orientation is preferable, but

also east- and west oriented facades are possible, leaving room for courtyard buildings with well-defined outdoor space. Shading devices are very important, thus introducing Mediterranean architectural features that are not yet common in a Northerly climate. The mixed-use possibility typically results in non-dwelling functions placed on north-eastern corners with little sunlight. Also the zero energy standard which includes electricity for household appliances, are met. This is typically done by placing highly effective mono-crystalline solar cells on major parts of the roof scape. The integration and detailing of solar cell panels in general still awaits some design attention. Usually the indoor climatic criteria are also reached, taking more simulation and calculation-power than the energy-part itself. Though being zero energy-buildings they are still connected to the urban heat- and power system giving backup especially during wintertime.

The achieved housing qualities encompassing functional and aesthetic aspects are harder to generalize, but some tendencies are clear: Being given the possibility of an urban density between 100 and 200 % most students quickly settle for the lower end of the scale and densities between 100 and 130 %, which secures easier access of sunlight. Some may argue that this is not really high density building, but for a 3-5 story 150.000 person Danish city it does not seem out of place. Cars are placed under ground leaving room for green urban space, bicycles and pedestrians, playgrounds and sports area above ground. This generation of students seems to very quickly adapt to the idea of cities not dominated by cars. Concerning private outdoor areas such as balconies and terraces one may trace the student’s different climatic backgrounds: Scandinavian students will often go for Southern or Western orientations, whereas students from Southern parts of Europe might include also other orientations thus giving way to a broader variety of urban layouts. It might be added than balconies are often consciously designed to work as shading devices for the apartments underneath. The design of urban space, semi-private and semi-public areas differ greatly from to group. Also the roof-scape may work as semi-public space.

In the housing units much attention is paid to daylight qualities, often with living rooms spanning from façade to façade thus getting daylight through two opposite outer walls. The depths of buildings are seldom more than 12 meters securing good daylight levels also in the center parts of the apartments. Deeper buildings are an easy way of providing more housing area, higher urban density and probably also better economy, but in this case the students choose to prioritize well-lit apartments.

In spite of some common tendencies, the housing complexes are very different in design showing that sustainability and zero energy do not have to cause uniformity. In most cases sustainability seems not to limit but rather inspire the architectural design.

6. Final comments

Planning, designing and constructing sustainable built environments calls for considerations on a number of physical levels from regional climatic conditions, soil and topography over urban fabric, infrastructure and greenery to the size, form and texture of buildings and the detailing of constructions. It involves a high number of stakeholders who work on different scales and in different phases before, during and after construction. Even though all involved may have the best intentions of building sustainable the realized designs will often be far from optimal due to lack of cross-disciplinary understanding and awareness and the fact that we operate with different kind of mind-sets whether economical, technical, social or aesthetic.

The educational program described above does not claim to include all aspects of sustainable design but it encompasses three major aspects and allows them to profoundly influence the building design: The first being dense settlement in order to reduce the environmental impact from transportation, to reduce the use of land and to increase the efficiency of infrastructures. The second being low energy consumption and local energy production that in northern climates involve passive and active solar which is difficult to obtain in dense urban areas. The third being that most residents like to have access to private or semi-private outdoor spaces; that residents especially in the Nordic countries prefer to have well-lit housing units and that children families in general benefit from being close to green areas and playgrounds. This is difficult to achieve in areas of high urban density, but the ambition must be addressed in a sustainable perspective.

7. Conclusion

The many student designs on mixed-use zero energy-housing that have been carried out based on the before-mentioned curriculum and project description show that sustainable forms of settlement and good residential life can unite and that a dense human biotope reaching zero energy may be an attractive one. This is difficult to achieve and takes integrating design skills that carefully merges technical, social and aesthetical criteria and considerations, which is not self-evident in contemporary building practice.

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Sustainable neighbourhood in Saint-Petersburg

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Summary

Urbanization and massive construction in Saint-Petersburg set new questions in front of architects and urban planners. This work is an attempt to analyze current situation in urban development, identify the problems and suggest the ways of possible solutions.
The dominant urban development strategy could be described as unsustainable with outer expansion, extension of transport links and complication of energy supply systems, and based on this, decisions of location and new urban development strategy for the practical proposal were made.
Three common urban forms were taken as case studies, compared by average number of storeys, building distance/ building height ratio and other parameters and then they were analysed by Ecotect 2011 Simulation Tool in terms of some aspects of environmental performance. Based on these calculations proposing building configuration and the planning system of a new district were developed. Some important aspects of a planning stage of new neighbourhood were considered, as the following: building conservation, alternative transport concept, some aspects determining urban quality of an area. At last, this paper describes energy supply concept with short overview of available alternative energy sources. Than the study proceeds to a single-building scale observing design methods increasing energy efficiency in given climate conditions.

Keywords: inner-city development, mixed use, rehabilitation, alternative energy sources

1. Introduction

Constant outer growth of the city combined with lack of legal instruments for managing projects in a sustainable way leads to a list of problems in current city development and it could cause more problems in the future concerning economic sphere, people well-being, increasing pressure on the environment etc. Saint-Petersburg took a second place in Russian Environment rating among big cities in 2011, but requirements for energy efficiency are still low and some aspects of environmental performance of buildings and neighbourhoods are not being taken into consideration on planning, constructing and operational stages.

2. Urban morphology of Saint-Petersburg

Founded in 1703 Saint-Petersburg has always had high growth rates. Now it is one of the biggest cities in the country, large cultural and touristic centre and also along with Moscow a place of permanent construction.
Mass residential construction has started in the city during Soviet period, mainly located beyond the industrial “belt”.
Currently large developing companies invest their money in different projects. Since 2000 the city urban development strategy has changed. The construction inside the city has almost stopped, and for now the tendency of constant external growth of the city remains the dominant.

2.1 Urban Form A: Historical residential quarters
Urban Form A is located in one of the “painful” spots of the city. Buildings in this district were built at the beginning of XX century and are mainly represented by 5 – 6 storey buildings with small enclosed courtyards (so-called “yard-wells”), overage building distance is about 12 m. In terms of climate adaptation this configuration allows to avoid some heat losses in windy climate of Saint-Petersburg. On the other hand enclosed courtyards may contribute to formation of a “turbine-effect” when the wind velocity is higher than a particular level which does not serve to heat conservation.
Nowadays these buildings do not meet current standards in terms of green and public spaces availability and some hygiene requirements, e. g. solar accessibility.
Even though the brick walls of old buildings may achieve 50 – 80 cm across (but with no additional insulation materials), it can not store heat inside buildings because of numerous cold bridges, especially in wooden windows.

2.2 City Modernization. Urban Form B
Urban Form B is taken from one of new districts outskirts of the city as a case study of dominant urban development strategy. Mainly it is represented by high-rised residential buildings (about 26 storeys) with some public areas on a basement floor. Average building distance is about 60 m; average number of storeys is 26.

Lack of human scale and high energy consumption (energy demand for extension of traffic lines and for energy support of high-rised buildings) should be named as major disadvantages of such an urban form. Also this type of spatial organization (tall buildings, big building distance) leads to formation of “hollow” spaces belonging to nobody and without additional landscaping this territory between the buildings will not be used by the residents even though spaces are large. In terms of social aspect outlying districts are commonly not supported by a sufficient number of educational and medical institutions as well as facilities for leisure and cultural life.

2.3 Elite residential quarters. Urban Form C
Among advantages of this residential district type could be named: human scale (average number of storeys: 5-6, building distance: 17 m), low energy demand (because of the location and building configuration), car-free zones, availability of green areas; among disadvantages - lack of additional facilities (monofunctionality), “closed” elite type of a district. Therefore even though urban quality of these new areas is relatively higher than in other parts of the city it does not affect urban quality in a bigger scale on a city level.

2.4 Conclusion. Urban Development

Common disproportion in spatial development of Saint-Petersburg is caused by number of reasons connected with extensive model of the urban development. Among those should be named: great difference in population density between historical districts and new districts under construction (10.000 people per m^2 and 1.000 people per m^2 accordingly). At that time the biggest number of workplaces is located in the city centre (about 50 % of workplaces are located on less than 25 % of the territory of the city). Average salary in the city centre is significantly higher than in other districts and the most densed city districts are provided by the least number of work places.

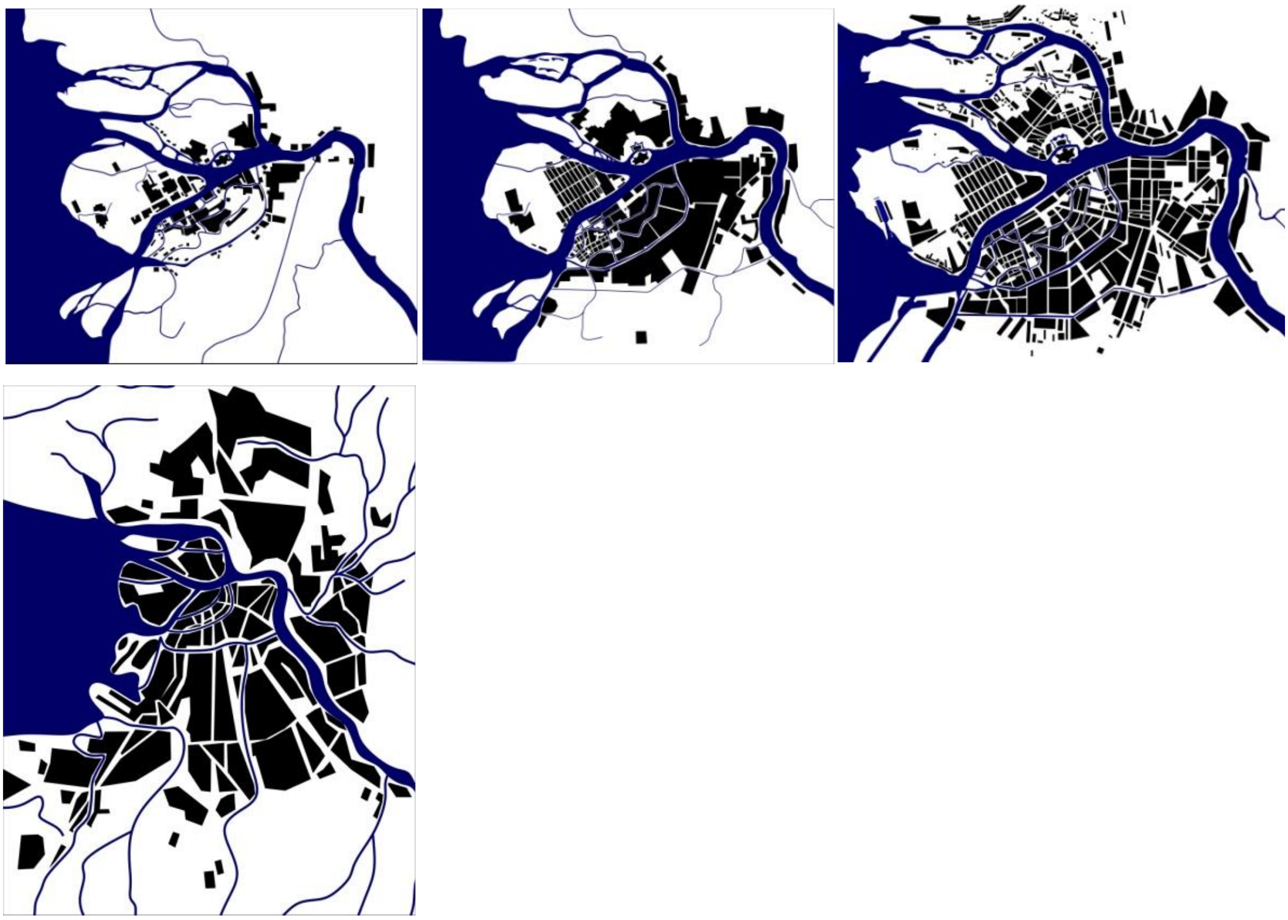

Fig. 1 Urban expansion in Saint-Petersburg. Own images. a – 1725, b – XIX cent., c – XX cent., d – 2015

All together it leads to daily pendulum migration flows and increasing load on the transport system. Urban expansion forms the following problems in the city development:

- Low accessibility and low connection between different parts of the city. As a result, accessibility of workplaces is about 56 minutes, which is 25 % longer than in settled standards of living.
- Engineering support of new districts follows the market. That means that questions of energy and water supply are being resolved “backwards” after the planning stage. This strategy leads to lack of power reserve of a number of energy resources in some new districts. Therefore in the future the city is going to become more wasteful and expensive for any kind of large-scale activities.

2.5 Conclusion. City Master Plan

Stability, balance, reconstruction and organic growth were named as the basic principles for the city future development in terms of sustainable development as a priority goal for Saint-Petersburg.

In a discussion dedicated to the new city master plan the most criticism was met by the fact that non-financial life quality aspects such as environmental security, green areas preservation, democratic participation in a decision-making process, reduction of environmental impact do not figure as priorities.

The main problems of the city remain those with transport system, household municipal waste management strategy, public green areas, energy efficiency, health of the population, business social responsibility.

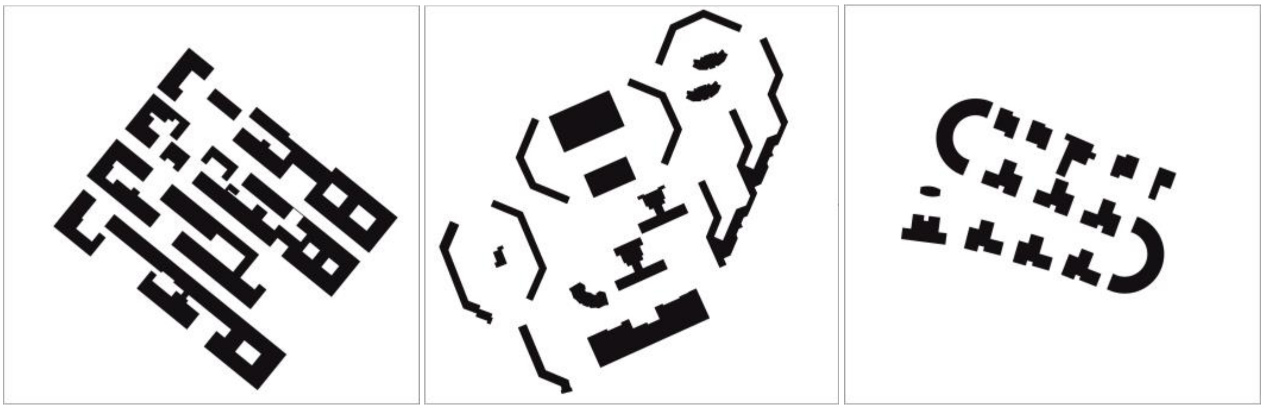

Fig. 1.2 Urban Form A in 200x200 m block, B in 400x400 m block, C in 200x200 m block. Own image

Table 1: Urban Form A,B, C, Urban Density, Ratio Building distance/ Building Height

	Urban Form A	Urban Form B	Urban Form C
Average Number of storeys	4,6	19,8	4,3
Ratio Building Distance/ Building Height	0,88	0,9	0,91
Urban Density (Area of Use/ Area of Estate)	1,7	1,1	1,2

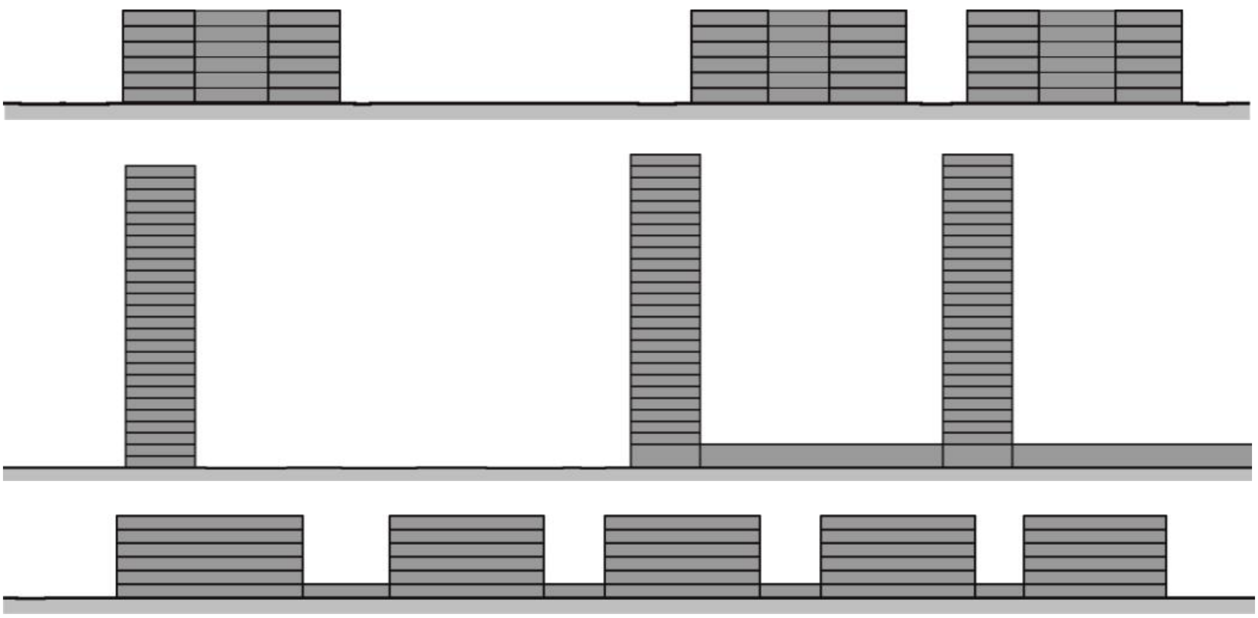

Fig. 1.3 Urban Form A, B, C Sections. Own image

3. Environmental Performance of Urban Forms.

3.1 Ecotect 2011 Simulation. Solar Access

In order to define an urban morphology of a new planned district it was decided to compare existing urban forms using Ecotect 2011 Simulation Tool. Rough comparison contains solar access indicators: shading and direct sunlight access.

Saint-Petersburg is a city with high humidity and high precipitation level. Sky view is generally cloudy which means lack of sunlight especially during cold months. Therefore one of the important tasks in the building design for this region is to provide sufficient access to sunlight for psychological and physical well-being of building's users.

According to local urban regulations for residential and public buildings it is required to have sunlight indoor during at least 2.5 hours for the period from 22 April to 22 September. These parameters are quite low and could be increased in order to raise the comfort level.

3.1.1 Shading

In simulation average direct sun hours per day units were used for Solar Access calculations. Calculations were made for summer and winter periods.

Urban Form A can be merely described as a comfort living area because of dense shadows inside the courtyards during both winter and summer periods. Since these quarters had been built before modern regulations were set, they do not correspond contemporary solar access requirements. In apartments oriented on the courtyard side, the direct sunlight is available only for two top floors. The accessibility of sunlight is also reduced for those apartments located on the first floors with windows orieneted on narrow streets.

Significant building distance in Urban Form B leads to a better solar access in summer time, however high-rised buildings cause long shadows and therefore results for the winter time slightly differ from the previous type. Besides large open spaces are exposed to strong radiation in hot periods (normally in summer there are two or more weeks with the tempereture close to +30° or higher), which makes inhabitants feel the temperature higher on a ground level.

Results for Urban Form C can be described as satisfying with good building orientation, sufficient solar access and proper building distance.

3.1.2 Radiation

According to the daily radiation analysis of the ground the fewest amount of solar radiation is received on the ground level in old quarters (Urban Form A). In modern districts (Urban Form B) the amount of receiving solar radiation is significantly higher in summer and relatively high in winter. Plus, extended envelope area of high-rised buildings increases the accessibility of daylighting and provides better opportunities for natural ventilation using. On the other hand, reduced roof area decreases the possibilities of using solar energy for building power supply (in terms of the correlation between building surface and volume – Passive Potential). Urban Form C can be described as receiving relatively high amount of solar radiation in summer; results for winter are in the middle among all three types.

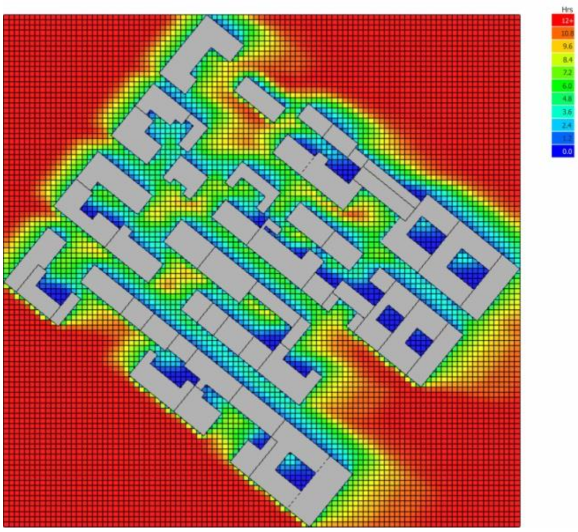

Fig. 2.1a, Urban Form A: Average Daily Sun Hours on Ground in summer (Jun. to Aug.). Image by Ecotect

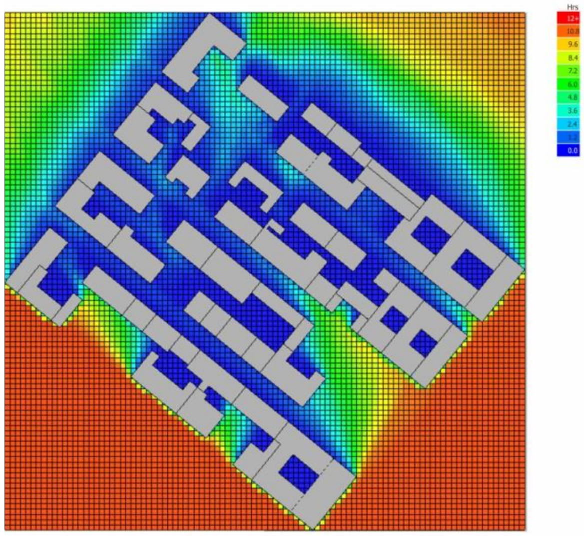

Fig. 2.1a, Urban Form B: Average Daily Sun Hours on Ground in winter (Dec. to Feb.) Image by Ecotect

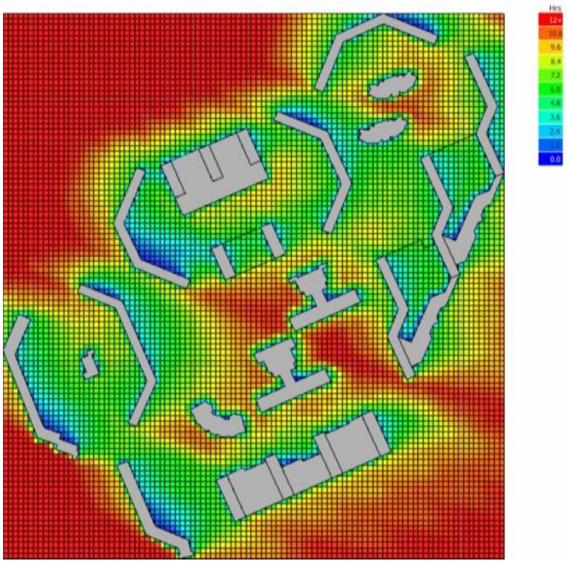

Fig. 2.1b, Urban Form B: Average Daily Sun Hours on Ground in summer (Jun. to Aug.). Image by Ecotect

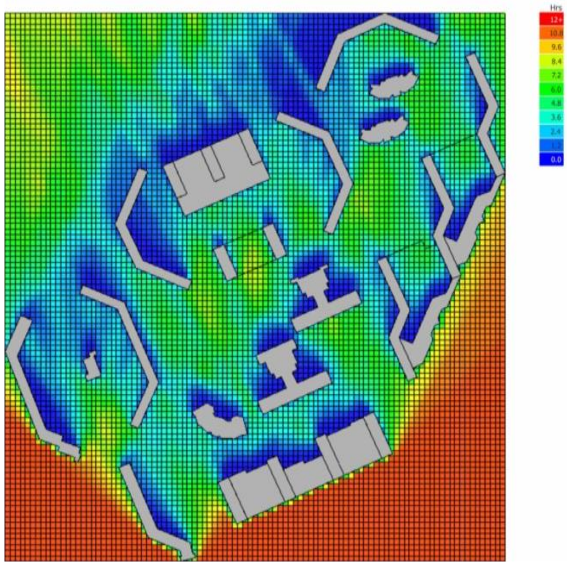

Fig. 2.1b, Urban Form B: Average Daily Sun Hours on Ground in winter (Dec. to Feb.). Image by Ecotect

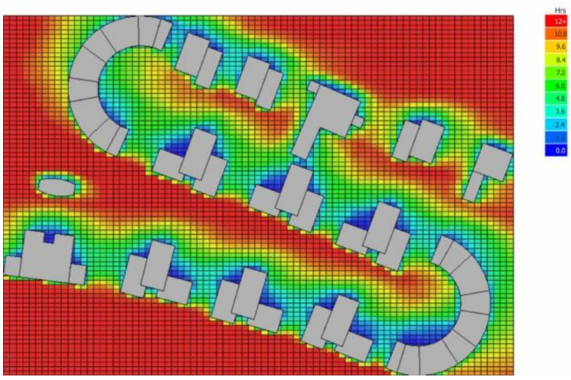

Fig. 2.1c, Urban Form C: Average Daily Sun Hours on Ground in summer (Jun. to Aug.). Image by Ecotect

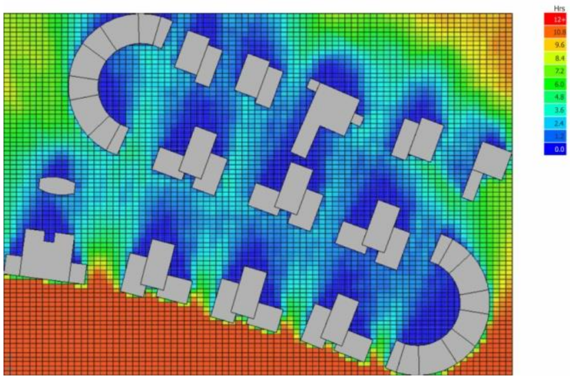

Fig. 2.1c, Urban Form C: Average Daily Sun Hours on Ground in winter (Jun. to Aug.). Image by Ecotect

An example of modern elite quarters (Urban Form C) shows the opportunities in creation of new urban environment – with less impact on the nature (no new transport links), less energy consumption, higher passive potential and offering better life conditions for its inhabitants (human scale). The problem is that having these opportunities, modern technologies and materials there is still a little chance to implement it in a city scale. An economical issue remains dominant in this matter. Good location in a city centre, high-quality building materials, landscaped area etc. makes the prices higher. And in case people can afford a property in this area they will prefer to secure their place of living and make it closed to publicity. That means that new elite districts may appear, function and develop separately from the city. So the live issue is not solely about designing of a new neighbourhood with better qualities but also about making it more affordable and more open to the city, integrating it into the urban environment.

4. Sustainable neighbourhood in Saint-Petersburg. Proposal

The location of a proposing neighbourhood is on Petrovsky Island – the territory in the city centre, surrounded by flows of Neva River. At the moment there are five bridges (four – bridges for vehicles, one – for pedestrians), all located on the north side of the Island. The territory has an access to two subway-stations (about 15 minutes on foot), and there are two public transport stops located on the main street of the Island - Petrovsky prospect. The Island has long and narrow shape which runs from south-east to north-west. The main places of attraction are sports stadium “Petrovsky” (one of the biggest in the city) on one side and the River Yacht Club on the other.

4.1 Current situation, plans for development.

For many years, the Territory of Petrovsky Island was a cause of confrontation between developers. Being one of the industrial districts in the past nowadays Petrosky Island is one of the most attractive and potentially profitable areas for construction. This can be explained by central location (transport accessibility, neighbourship of historical centre, services), availability of green areas and access to water.

Recently plans for the development were determined decisively and the construction on the Island has already started. New development plan includes construction of residential quarters, commercial objects, schools, hospitals, hotels etc.

Since the land on the Island has several owners it is important to mention that only strong cooperation between developers, architects and the whole team working on projects could provide the unity of this neighbourhood and serve the development of the territory in more sustainable way.

At the moment the only requirements new development should follow are local urban requirements common to the whole region, proposals also should be developed in accordance with the city master plan. The suggestion is to develop new standards particularly for this neighbourhood with some comfort requirements, requirements for landscaping and greenery of the area, building functions, higher standards for energy efficiency, use of ecofriendly materials, indoor air quality etc. Then some non-commercial organization not owning the land in the neighbourhood could manage the adherence to set standards of developing projects.

4.2 Proposal

4.2.1 Conservation

Due to some configuration features of the Island and the type of development currently the following problems could be observed:

- Obstructed access to water;
- Lack of pedestrian paths;

- Lack of parking places (cars parked on a sidewalk);

At the moment Petrovsky Island could be described as “unfriendly” environment for the walker/ cycler with lack of greenery and limited access to the most parts of the territory. Closed type of development is caused by a large number of industrial objects now abandoned.

Yet numerous objects on the island are considered as cultural heritage (e. g. House for veterans of Scene), some others are objects of urban values (River Yacht Club, stadium “Petrovsky”). A map of conserved and constructed buildings according to this proposal is represented below.

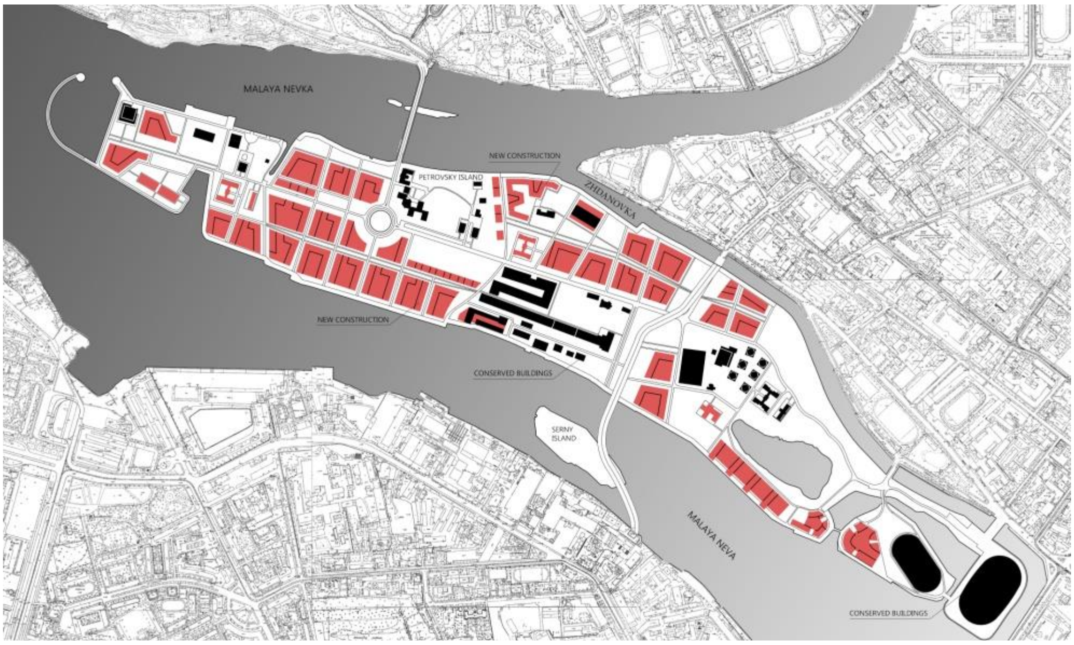

Fig. 3a Sustainable neighbourhood on Petrovsky Island. Conserved buildings are shown in black, new construction – in red colour. Own Image

4.2.2 Transport

Choosing transport concept is one of important factors in forming the sustainable heighbourhood. Even though the location of proposed district is isolated (on the island) at the moment it seems impossible to exclude motor vehicles completely. Especially considering that Petrovsky Island is supposed to be included into the urban transport network in a short time by the construction of new motorway and the bridge. Nevertheless, some of measures can be done as the following: encouraging the development of non-fuel urban public transport (trolleybuses, trams), limiting the car-use inside the living area, promoting the use of electric cars, points of electric cars-to-share. Besides due to availability of green spaces and proposed development of public spaces there is an opportunity to develop cycling on the island by creation bicycle paths network. Moreover the location on navigable tributaries of the Neva River allows using of electric-powered boats.

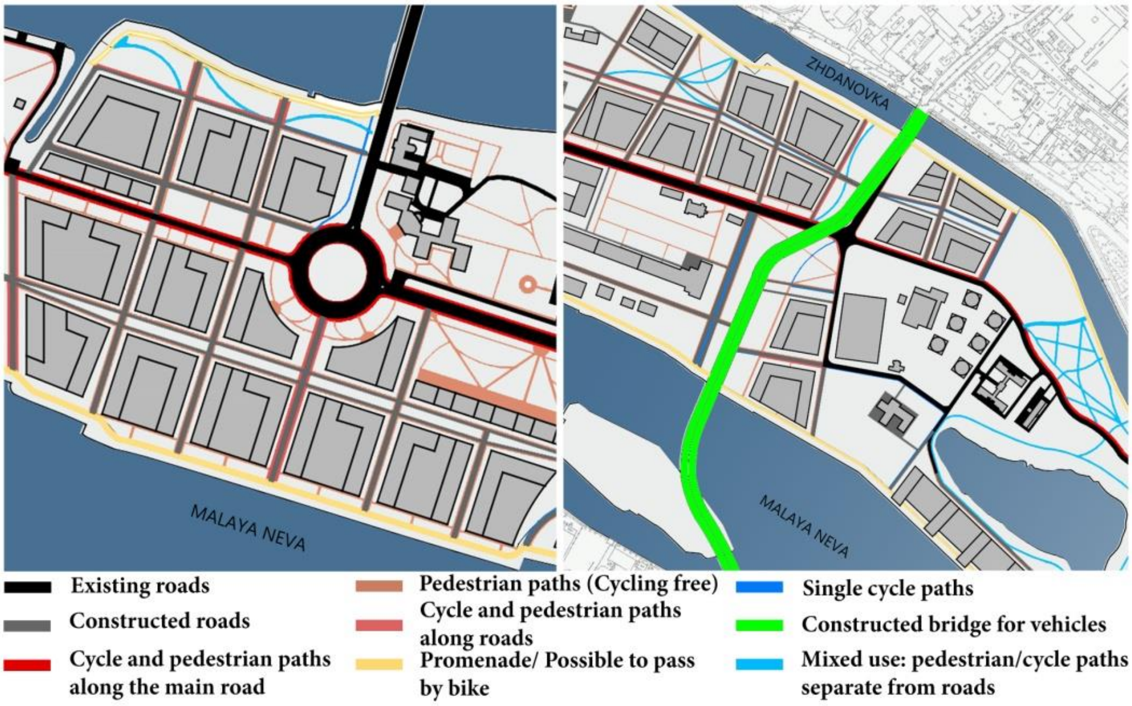

Fig. 3b Sustainable neighbourhood on Petrovsky Island. Cyclintg concept. Own Image

4.2.3 Functional Zoning

Seeking to car-free alternative all the courtyards are elevated above the ground. It helps to split the transport streams and limit the car access inside the residential quarters. Basement floors are equipped by parking places, first (plinths) floors are supposed to be filled with some local services – groceries, laundries, hairdressing, cafes etc. Public access to the first floors increases an urban quality of a district. Multifunctionality contributes to the common good of the area too. Current development plan doesn't imply to have any office buildings on the island, whereas it could provide workplaces for some residents and to attract workers from the neighborhood. Some of low-rise residential buildings on the island with the status of the heritage may be renovated and converted into museums, and their inhabitants could be settled in new buildings around.

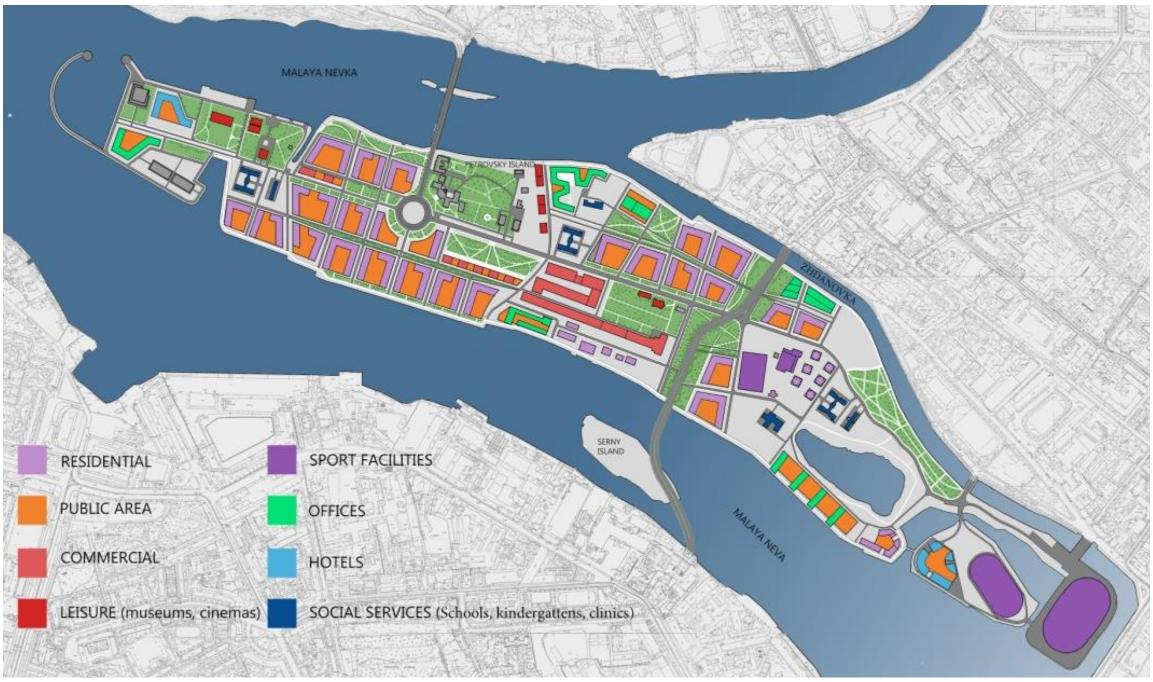

Fig. 3c Sustainable neighbourhood on Petrovsky Island. Functional Zoning. Own Image

4.3 Alternative energy sources

In this project it was decided to not exclude the public energy supply system completely but try to reduce energy supply from non-renewable sources and use alternative energy sources as supplementary.The task was to analyze available renewable energy sources in order to build energy supply strategy in the most beneficial way.

Saint-Petersburg is located in moderate climate, on average there is 62 sunny days per year. Therefore using of solar energy can not be assumed as the most efficient for this region. Nevertheless it was calculated that about 1240 Em (average monthly electricity production kWh) can be produced by 2-axis tracking system of PV modules. Due to the high costs this system can be replaced by the vertical tracking system (inclination=58°) with total result 1230 Em or the fixed system (inclination=35°, orientation=0°) resulting with 912 Em. The best placement of the PV modules is on the top of buildings according to the calculation of receiving amount of solar radiation.

Local hygiene requirements exclude using of cross ventilation in residential buildings in case two apartments are oriented on the opposite sides of a building separated by a corridor. Though Saint-Petersburg has good conditions for using natural ventilation (the wind velocity is generally higher than 3 meters per second). Using of ventilation shafts therefore is assumed to be an optimal solution for this region.

The difference between outside temperature and the ground temperature enables using of heat pumps. The suggested strategy is to use the ground temperature to heat/cool the supply air for airing. System of water tubes built into the ceiling may contribute to temperature control of buildings in winter time. The water in tubes will be heated by the ground temperature before entering the room.

Other strategies: Using of massive constructions is preferable for passive heating/cooling of a building; Glazed balconies on facades receiving greater amount of solar radiation (south, south-west orientation) for passive heating in winter time. Set standards for residential buildings in proposal: number of storeys – 6 (including stylobate), housing width – 20.4 m, courtyard type (not fully closed for better solar access), width of the courtyard – 45 - 50 m.

5. Conclusion

Saint-Petersburg despite its historical status is a modern developing city. Since the rates of its territorial growth, energy consumption and growth of environmental impact become distressing, significant changes in its urban development strategy, construction methods and requirements related to energy efficiency and reducing the pressure on the environment should be made. To say more generally, something has to be changed in planners, builders and users attitude, and these changes have already started in low rates.

This proposal develops the new urban development strategy, which excludes expansion of new territories, involves development of abandoned territories in the city centre and increases the availability of these areas in a city scale.

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Sustainable Public Procurement of construction works – a literature review and future requirements

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Summary

In today's economy a growing interest in "greening" the construction industry can be recognized. Therefore the procurement of construction works opens up an important opportunity for implementing not only environmental aspects into all processes as well as products of a building. Furthermore it contributes to a reduction of the environmental impact caused by construction actions. Purchasing of construction works therefore is potentially a powerful agent of change towards a more sustainable portfolio management of building projects.

In recent years, the interest in the cross-disciplinary area of procurement research (used interchangeably with green purchasing, environmental purchasing, sustainable sourcing and supply management) continues to grow in both academia and industry. A main driver of this development is the increasing number of policies and regulatives dealing with these issues of procurement (e.g. COM (2008) 400 focusing on green/environemental aspects in the procurement process; Directive 2014/24/EU on public procurement repealing Directive 2004/18/EC)

Various research examine the positive effect of green and environmental purchasing as a useful instrument that improves resource efficiency, promotes recycling and other environmental benefits. But for a holistic consideration not only environmental aspects should be targeted. In terms of sustainable procurement of construction services also economic and social aspects should be considered besides ecological issues.

The aim of the paper is the review of existing evaluation approaches in public tendering and awarding of construction works, focusing on how they assess the use of sustainable issues in terms of dealing with life cycle management in the procurement of construction works. However the environmental pillar of sustainability seems to be very popular, by phasing out hazardous materials in produced products and services, furthermore requiring a certain amount of recycled content or focusing on lower energy consumptions of buildings.

Finally a more performance-orientated approach could be recognized through this research. There are many research efforts towards a more cooperative procurement. Especially joint specification, selected tendering, performance-based bid evaluations, collaborative tools have direct effects on the project performance towards its life cycle.

Keywords: Green Public Procurement, Sustainable Public Procurement, Selection Criteria, Procurement Process, Holistic Approach, Literature Review,

1. Introduction

The increasing awareness of climate change implies the needs towards more comprehensive strategies especially in terms of public policies design. Construction industry is one of the most energy and resource consuming industries. About 40 % of the global energy use is related to buildings as well as 50 % of the resource consumption is linked to construction activities. Therefore the implementation of strategies is one of the most crucial aspects in this field of research. Public procurement can be seen as a major tool to implement these approaches into a more holistic life cycle consideration in construction industry [1]. Each year around 19% of the EU's GDP is procured by public authorities.

Therefore several strategies have been developed on international and national level in the last few years to strengthen the impacts of public authorities. The directives 92/50/EEC, 93/36/EEC and 93/37/EEC and 97/52/EC targeting coordination of procedures for the award of public service contracts on European level. In 1996 public procurement in the EU explored the way forward and in 1998 the white paper on public procurement in the EU was announced, COM 96 (583) final and COM 98 (143) final. In 2001 the EU commission published an interpretative communication on *"Community law applicable to public procurement and the possibilities for integrating environmental considerations into public procurement"* (COM(2001) 274). Followed by the European directive 2004/18/EC describing two different bases for awarding of contracts, 'the lowest price' and 'the most economically advantageous tender'. This shows the need to set up additional criteria to support the decision-making process in terms of selecting the tender not only based on the price, supporting future developments for further implementation of GPP by the contracting authorities. In a first step the awarding of contracts in this context is related to the acceptance by the procuring authorities. This has been repealed with directive 2014/24/EU also providing better access for small and medium-sized enterprises.

The current situation in construction industry is characterized through highly competitive markets. Accompanied, service and quality is suffering as firms have been forced to cut costs in order to survive these harsh conditions. Public Procurement therefore has a crucial influence and especially towards a life-cycle-orientated and sustainable development. Especially the 'most economically advantageous' tender is suited best, fulfilling the numerous criteria set by the public purchasers. For a better understanding of the performed literature review and the explored requirements for sustainable public procurement, the main definitions are listed below.

1.1 Public Procurement

Public procurement is a main driver for implementing sustainability aspects into the procurement of sustainable construction services. Due to the market size and potential related to public contractors, especially the public sector should lead the market and influence the private sector towards a more sustainable building supply chain [2].

1.2 Green Public Procurement (GPP)

GPP means that public authorities seek to procure goods services and works e.g. buildings with a reduced environmental impact over their life-cycle compared to goods, services and works with the same primary function that would be procured otherwise.

Therefore GPP was determind by the commission as *"a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwiese be procured"* (COM(2008) 400 final).

1.3 Sustainable Public Procurement (SPP)

However, in GPP the focus is just only on reducing the environmental impact of the products and services whereas SPP targets all three pillars of sustainable development (ecological, economical and social aspects), not just the environmental issues.

2. Research Method

A systematic literature review was conducted as a necessary step in structuring a research field and provided a systematic classification of the thematic area [3]. Performing a literature review is a systematic and reproducible design for identifying and evaluating scientific publications [4].
The articles analyzed in the following comprise peer-reviewed English language papers, which are focusing on GPP/SPP during the time period from 1990 to mid-2015. The key words used for selecting the articles are ‘Green Public Procurement’ and ‘Sustainable Public Procurement’, with a special focus on construction in the title or in the abstract.
In a first step, papers in academic and applied databases have been identified that contributed to green or sustainable public procurement and construction works. The databases were provided by major publishers like Scopus (www.scopus.com), Sciencedirect (www.sciensdirect.com), webofknowledge (www.apps.isiknowledge.com) and Emerald (www.emeraldinsight.com). However, during the process of analysing the databases, a focus was set on articles that were investigating specifically green or sustainable public procurement. Especially the interactions of public procurement and construction works.

Descriptive analysis

Based on the common awareness and of sustainable construction issues and the first European directive in 1992 the time period for the selected publications were chosen from 1990 to mid-2015 (Fig. 1). Since 2003 increasing research could be recognized based on the number of publications. Overall 135 articles have been considered in this research. A similar literature review on green procurement has been done by Appolloni et al. [5]. Their research focus was mainly based on private procurement, which indicated the need for an up-to-date review of public procurement, since the awareness of sustainability on this topic is increasing as well. Therefore in this study not only green public procurement was investigated but also publications on sustainable construction procurement were taken into account. This indicates the development towards a more holistic

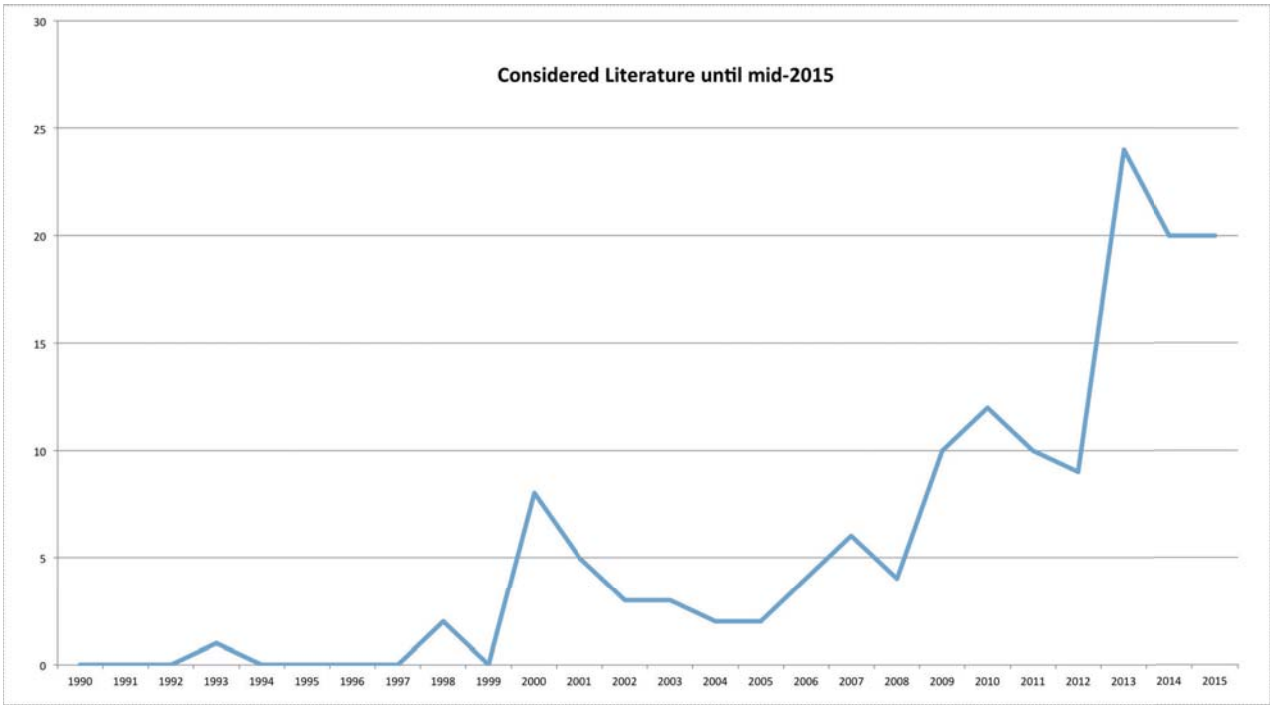

Fig. 1: Distribution of publications

approach in construction industry. Additionaly the works of CEN/TC 350 on internationally harmonized approaches on the assessment of sustainable buildings have to be mentioned in this context, which deliver the basis for a set of indicators to assess environmental impacts of buildings (e.g. EN 15804; EN 15978 on sustainability of construction works). The performed literature review showed, that there are various activities in different countries [6]. Starting from policy development to procurement issues [7],[8] and also focusing on the supply chain [9].

3. Thematic findings

Reviewing the scientific publications several recent trends became obvious:

- The trend of green and sustainable issues in procurement publications continues unabated and the range of published topics increases significantly.
- Topics of research areas like procurement performance, new experiences with e-procurement and case studies of adapting GPP/SPP for a specific region are published with a raising tendency.

The main drivers of such a development are regulative policies and legal restrictions (COM 2008 400; Directive 2014/24/EU). Based on the drivers there is the need for certain criteria to base the tendering decision on as mentioned in Rietbergen and Blok [10], who suggest using a life cycle assessment (LCA) for determining the environmental performance. Following their approach, LCA according to ISO 14040 should be stated to guarantee a more precise implementation of sustainability aspects in the tendering process [11]. This would also help to define a common baseline to compare the different offers at the procurement stage.

Based on the comprehensive literature review the main findings are presented and described in the following chapters concluding with future requirements on sustainable public procurement.

3.1 State-of-the-art on public procurement

An important step is to provide connections between sustainablity policy goals included in the public tenders and their achievement through awarding the contract as mentioned by Amann et al. [12]. They performed a survey of 281 procurement files form 2007 to 2009 in EU member states on different product categories and demonstrated, that the strategic use of public procurement influences environmental and socially related goals.

In general green procurement is focused on products, but the weightening is often very low and seldomly affecting the awarding decision stated [13],[14]. Nonetheless, it can be seen as a demonstration of high environmental ambitions in a projcet.

Additionally problems like project delay and the desire to simplify the project are listed. The procurers also listed increasing costs and limitations to the project. Environmental issues during construction tend to be more common in civil engineering contracts using environmental management schemes (EMS). Therefore the use of expert judgement is the most frequent method for formulation these requirements and criteria. Regular meetings and self-inspections as well as revisions are used to monitor the requirements. EMS are often used to proof the tenders ability to deal with environmental issues during the project.

3.2 Environmental criteria

Innovative technologies with regard to improved energy and material efficiency have been implemented in public procurement. A crucial aspect therefore relies on the role of life cycle assessment (LCA) as a decision-supporting tool. Butt et al. [15] investigated the role of LCA as decision support in road procurements. Tarantini et al. [16] did a case study on windows using LCA or

criteria definition. Overall a crucial role is on the feedstock of the data and the system boundaries need to be compareable as a result from a case study in Belgium [17]. It is very essential for indicating sustainability aspects of a product to communicate their environmental performance. An Environmental product declaration (EPD) informs interested parties about the environmental performance characteristics of products. They are based on LCA according to providing its results as inventory or impact category indicators. The concept of EPDs has also found a market in the construction sector and is a considerable part of the European integrated product policy [11].
Overall LCA based environmental award criteria need to be in line with the legal procurement frameworks as a case study in Finland [18] reported on transport distances potentially discriminating some bidders.
Another approach focuses on the reuse of excavation material as an awarding criteria [19]. Also recycled materials combined with small price inventives can lead to a significant reduction of construction, demolition and consequently on environmental impacts [20].
Environmental aspects of products are also linked to the rise of building certification schemes (like BREEAM, LEED, BNB/DGNB/ÖGNI) [21]. Hence ecolabels are preferably used because they count to green building points [22] and the sustainable performance is communicated through the certification scheme as Xia et al. [23] investigated on LEED.
Environmental aspects of the construction phase have been investigated by Osebold et al. [24] focusing on the construction process. Also Varnäs et al. [25] in their practice report on the city tunnel in Malmö focused on combining environmental impact assessment, environmental management systems and green procurement. The use of environmental management systems is suggested to create a link between the environmental impact assessment and the contractors environmental management systems.

3.3 Barriers and limitations of GPP/SPP

Public procurement is seen as an instrument for innovation policy, therefore a change of view is necessary. Barriers arise from budget cuts, backward thinking in terms of preferring average suppliers over innovative and sustainable ones, as investigated by Georghiou et al. [26]. Furthermore policies are linked to ministries or agencies, not directly to the budget holders, therefore they do not necessarly have the same commitment or understanding of innovation and sustainable procurement on the whole life cycle, stated by Monahan et al. [27] and Uyarraa et al. [28].
In a case study in Finland, Sweden and Denmark [29] the tenders are mainly based on the most economical advantageousness, around 90 % of the purchase decisions. Besides price, quality, delivery terms, also environmental aspects and social factors are considered. The meaning of environmental aspects is not always well defined and thus it is problematic to fulfill or verify, and to use it in the awarding decision. According to their study the weightening ranges from 5-20 % that means, it is not clear if they really matter in the awarding decision. This raises a thematic extention, not only focusing on environmental aspects, also taking life cycle orientated processes into account, therefore Uttam et al. [30] are suggesting a more performance-orientated approach. Besides the European directives, the rise of certification systems of federal governments like the assessment system for sustainable building (BNB) in Germany has a strong impact sustainable public procurement. But these systems for public buildings are not very common in other countries like France or Austria, therefore sustainable public procurement emerges slower.

3.4 Performance impacts of GPP/SPP

Based on the legal frameworks with the use of the most economically advantageous tender, public purchasers are able to consider sustainable issues in their decision-making process [31]. This will support linking environmental qualities with economical advantages towards a sustainable project delivery. Applying policy directives, there is no clear understanding, how these criteria are going to assess the most economically advantageous tender in terms of environmental aspects due to a common baseline. Therefore contractor selection is a crucial topic. Safa et al. [32] considered the information and analysis of numerous uncertainties in construction contracts for major decision-making processes. They suggest the use of competitive intelligence (CI) to deal with these problems, which are related to the necessary information that is required for decision-making. This indicates recent research on focusing more on performance-based approaches. In this context collaboration becomes more important. Mokhlesian [33] investigated the situation in Sweden, and stated there is not such a big difference between green and conventional projects, but the suppliers green knowledge can be valuable to use. Therefore early procurement stages and contractor involvement can be helpful, in terms of pre-construction project partnering [34]. In the Netherlands a case study on Rijkswaterstaat, early private involvement has been experienced as a useful insturement [35]. It allows a better understanding of the procurement process and how project performance is achieved. A study by Love et al [36] indicated a tendency of greater involvement and interaction between the client and consultants for a more effective procurement process. This has been supported by Padding [37] mentioned two approaches which need to be explored further – namely a process-oriented approach and goal-oriented criteria.

3.5 Future directions / requirements

In a survey performed by Lam et al. [38] among construction praticipants in Hong Kong, they investigated sustainability requirements and changing priorities in construction management. They identified the principal factors leading to the success of prepairing green specifications (1) green technology and techniques, (2) reliability and quality of specification, (3) leadership and responsibility, (4) stakeholder involvement, and (5) guide and benchmarking systems. But the involvement by the stakeholders should be the most important factor for the preparation of green specifications. This supports the idea of early contractor envolvement e.g. Hwang and Ng [39]. More research on this topic has been performed by Eriksson and Westerberg [40] in their paper on a holistic procurement framework, dealing with a broad range of procurement related factors. In a literature review they are suggesting cooperative procurement procedures (joint specification, selected tendering, soft parameters in bid evaluation, joint subcontractor selection, incentive-based payment, collaborative tools, and contractor self-control). Their research showed a general positive influence on project performance (cost, time, quality, environmental impact, work environment, and innovation). Furthermore they confirmed, that the relationships are influenced by the collaborative climate (e.g. trust and committment among project partners). This is also supported by Kadefors et al. [41] focusing on collaborative inter-organizational relationships and the aspects on contractor procurement for partnering projects, similar to Pesämaa et al. [42].

4. Discussion and conclusion

Summing up the main thematic findings of the literature review, an overview to what extent procurement is utilized to foster sustainable development has been given. Public authorities are addressing sustainability through a wide range of initiatives. Following a holistic approach, sustainability aspects of building projects, quantifyable methods in terms of awarding and selection criteria are key elements in the procurement process and are already popular, especially focusing on environmental aspects. Nevertheless, terms of legal and normative boundary conditions need to be considered. From a holistic point of view, it seems that these approaches are limiting individual solutions and an integrated concept is often missing. However life cycle management need to be

applied. Starting with the implementation of sustainability aspects in early project phases by considering demands of usage and the life cycle of a building could help to push a more holistic approach. This is going to be done, not just only focusing on products - following a holistic approach - also processes in terms of project management need to be considered. Therefore building certification systems (such as BREEAM, LEED, BNB/DGNB/ÖGNI) are important for delivering project performance criteria on sustainable issues (e.g. environemental impacts, costs).
Unlike previous studies on green procurement, our study therefore also adds aspects on how the procurement process should be structured and gives a suggestion to start with the definition of requirements as a basis for the call for tenders in earlier project stages to include the knowledge of different experts from the integrated design team. It is often shown, that the normative guided approaches are not always successful in terms of dealing with a sustainable procurement.
Public procurement is often linked to innovation. Following a swedish case study [43] the lowest level of innovation intensity is mostly linked to the methodological trajectory, while the material trajectory dominated innovation. Collaboration therefore is associated with a higher intensity of innovation. As mentioned in [41], in terms of collaborative procurement, more research on systematic studies on how authorities and attitudes of individuals are attended to formalized procurement processes.
An important factor from this investigation relies on the weighting of these issues in the tendering process. A previously unrecognized factor in this context is also the qualification and experiences of the involved persons, which are going to perform the tendering process.
Additionally a very crucial point is the definition of a common baseline, right at the beginning of the call for tenders.
Furthermore, after procuring a life cycle orientated product or service, performance indicators are necessary to monitor the buildings' performance [44]. Additional research is required on meeting future requirements on e-procurement in context to building information modelling (BIM), new processes of collaboration need to be intensified, following Grilo and Jardim-Goncalves [45].

The paper is a first outcome of an ongoing research project, concerning opportunities and practicable solutions for implementing sustainability aspects into optimized project management and planning processes. The procurement stages and tendering elements are analysed based on legal frameworks to identify possibilities towards a more performance-based procurement approach.

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Sustainable Real Estate Education: Competencies and Didacdics for a Transdisciplinary Master's Program

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Summary

The real estate economy with its high impact on sustainability urgently needs graduates who employ a multi-perspective approach and are able to act holistically. The purpose of this paper is to provide a framework for competencies and didactics of a transdisciplinary real estate Master's program. Starting with the perspectives that should be addressed in sustainable real estate management, we find a lack of programs dealing with the interfaces. Higher education programs on sustainable development face similar challenges, therefore comparative research helps identifying requirements and effective didactics. Empirical research regarding a sustainable real estate Master's program in Germany confirms major analogies between both areas. Thus, proven educational concepts can be applied to develop an auspicious transdisciplinary real estate curriculum.

Keywords: Real Estate Education, sustainable Master's Program, Transdisciplinary Approach, Competencies, Didactic Concept

1. Introduction

The real estate sector is one of the largest industries in today's modern economies and affects everyone's life in multiple ways. [1] The topics to be considered when developing, producing, or operating, buying or leasing, investing or financing real estate are plentiful and heterogeneous. Moreover, real property has a large impact on sustainability. [2] This variety and complexity of real estate issues results in more and more specialists who are involved in real estate supply and demand activities and need to be led towards their respective individual or mutual goals. However, when sustainable real estate is the mutual goal, "generalists" are needed who combine holistic knowledge with distinct skills regarding communication and coordination to advance cooperation towards this goal.

At business schools, sustainability – understood as responsible management of resources – has been implemented in the form of additional courses rather than embedded as an attitude [3]. Nicolescu 1997 [4] already called for a more holistic and transdisciplinary approach together with a multi-dimensional opening of the universities inter alia towards the aim of universality and a new definition of values. Transdisciplinary approaches, as defined by Tress et. al [5], integrate disciplines and non-academic participants to develop integrated knowledge and theory with relevance for science and society. The difference to interdisciplinary or multidisciplinary approaches is the mutual goal as well as the interaction with the industry providing real life needs and knowledge.

Instead, real estate education has so far mostly been disciplinary and sometimes multidisciplinary. By moving to interdisciplinary or even transdisciplinary approaches that integrate technical, economic and social disciplines together with non-academic participants, today's pressing sustainability questions can be solved much more effectively. A noteworthy initiative towards that direction came from ZIA, the German Property Federation, which introduced a sustainability codex for the real estate industry in 2012 [6]. However, such a holistic, transdisciplinary approach has not yet been implemented into real estate educational programs.

The foundation for developing a sustainable real estate Master's program is the multi-perspective model described in the next section. The state of research in section 3 and the empirical findings in section 4 summarize the real estate education requirements in Germany. These form the basis for defining necessary areas of knowledge and skills of a sustainable real estate Master's program in section 5 and appropriate didactics in section 6. The discussion in section 7 identifies some of the challenges that arose when realizing the approach deducted from theory and empirical findings, leading to the conclusions in section 8.

2. Holistic Approach in Real Estate Education

Real estate and real estate issues are often dealt with from multiple perspectives but isolated disciplines. Kämpf-Dern, Pfnür and Roulac [7] proposed a perspectives model that includes four groups of actors and their motives when dealing with property: 'users', 'producers', 'investors', and 'regulators'. An important finding of the model and the accompanying empirics is that real estate research has mostly focused on "pure" perspectives issues that are the primary interest of only one of the actor groups. Investors' issues have predominantly been researched, followed by producers' and user's issues. Questions that address two or even three interfaces of the perspectives got the least attention. An explanation for this phenomenon – one that real estate has in common with other research crossing disciplines – is that inter- and transdisciplinary research requires knowledge and methods from multiple disciplines as well as the competency to communicate across borders of specialized languages, rare prerequisites in the past.

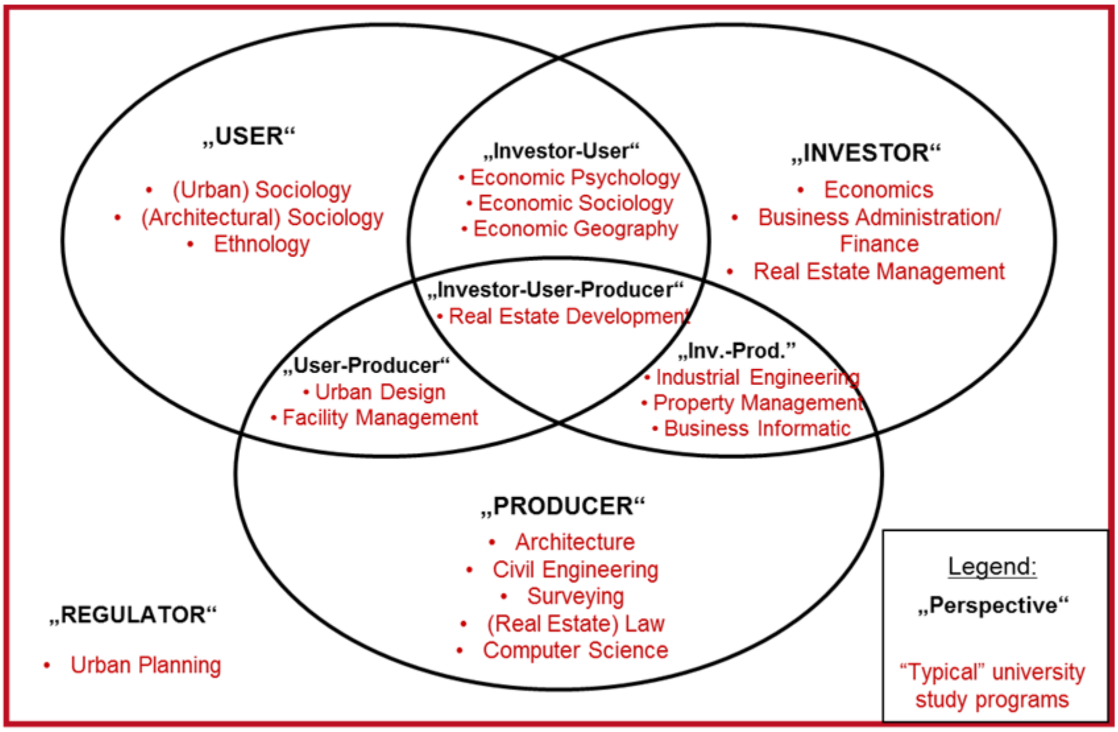

Figure adapted from Kämpf-Dern/Pfnür/Roulac (2015): Real Estate Perspectives as Dominant Cluster Attributes of a RE Research Framework

Fig.1 Disciplines and programs within the multi-perspective model

Figure 1 uses the framework of the perspectives model to structure scientific disciplines and educational programs addressing real estate issues. Programs on the interfaces have only been established in the last five to twenty years, unlike most of the “pure” perspectives like architecture, civil engineering, urban planning, economics or sociology. This development shows the trend towards a more holistic approach. Still, providing information from multiple disciplines does neither ensure the integration of science and society nor the integrated development of knowledge and theory. Examples of multi-disciplinary rather than inter- or transdisciplinary education are industrial engineering or economic geography, where one thematic umbrella – real estate – is taught in two distinct faculties. Other programs, such as property management or real estate development, have often been more practical than research-oriented, thus not systematically adding to knowledge generation or more generally valid solutions.

A transdisciplinary real estate program should provide students with a balanced set of knowledge from *all* perspectives, while simultaneously fostering skills to integrate them and to develop holistic approaches, preferably together with non-academics who ensure the relevance of the topics. With these prerequisites, graduates in the area of real estate should be able to better fulfill the requirements of sustainable real estate according to the understanding of the Brundtland Commission [8], the Triple Bottom Line [9], the ISO 26000:2010 – Social Responsibility [10], or the ZIA codex [11].

3. State of Research regarding Sustainable Education

In light of the international "Decade of Sustainability Education" (2004-2014) a tremendous amount of analyses and case studies regarding the requirements of sustainability in higher education and optimal didactic realization has been published in recent years. Many articles explicitly addressed a transdisciplinary approach [12], [13], [14], [15], [16], [17], [18], [19]. The most recent publication on required competences in the different fields of sustainability education includes four core competence groups: “systemic and critical thinking”, “anticipative thinking”, “social commitment”, and “ethical commitment” [20].

Scientific papers regarding real estate education mostly deal with the interfaces between university and employment. This is related to both the positive acceptance of graduates by later employees (in UK, [21]) and the need to closely connect the content of the program to real estate industry issues [22], [23], [24], [25], [26], [27]. Moreover, the relevance of internationality in the context of globalization is emphasized [28].

While real estate programs in the US have focused on economics for a long time and were mostly taught at business schools, McFarland and Nguyen [29] identified a trend towards the combination of economics and engineering outside of business schools. However, the third pillar of sustainability, addressing social issues, which in the case of real estate is about users and consumers and their needs, has not yet been on the radar. Even in real estate education literature dealing with accreditation standards regarding competencies of real estate graduates [30], [31], this aspect is missing.

On the other hand, sustainability issues in real estate have not been researched with regard to education. Instead, they either addressed the property level, e.g. the value of sustainability from a valuation view [32] or came from the practitioners’ point of view, e.g. how to implement responsible management. [33]

We therefore recognize a gap regarding the question of *what* – competence groups - needs to be taught in the multi-perspectives environment of real estate to integrate disciplines in such a way that sustainability becomes an attitude, and complex issues can be solved more effectively. Apart from the *What to teach,* the *How to teach* is not easy to answer either. In sustainable education, recommended didactics include Problem-Based Learning [34], [35], Cross-Discipline Learning [36], [37], Real Life Projects [38], [39], [40] and External Experts/Field Trips [41], [42], [43]. Additionally, the positive role of arts has been mentioned [44], but seems not relevant or feasible in real estate education.

Regarding real estate education, papers focusing on didactics are scarce but go into the same direction: e.g. using problem–based learning as an effective method in RE programs [45], or teambuilding as an important key for communication skills in real estate education in general [46].

4. Empirical Situation in Real Estate Education

The development of a sustainable real estate Masters' program can be based on two pillars: research and theories of comparable programs (as done in the previous section) and empirical exploration of the industry's needs, professors' experience, and students' preferences.

For the latter, a qualitative research was performed in Northern Germany [47]. Three important stakeholder groups - real estate industry members, lecturers, and students - were queried in a survey and semi-structured interviews. Additionally, member checks that were performed in workshops respectively focus groups added to the reliability of the results through triangulation [48].

The results – when compared within the competence structure of of Novo and Murga-Menoyo [49] for integrating sustainability in higher education – showed many similarities between Sustainable Development and Real Estate (see table 1).

Table 1: Competence groups and requirements in Sustainable Development and Real Estate

	Sustainable Development / Sustainability	**Sustainable Real Estate**
	S 1- Systemic and Critical thinking	
1	Holistic Approach	Integrated perspectives approach
2	Complex Interrelations	Complex Interrelations within and between perspectives; critical reflection of issues; problem solving
	S 2- Anticipative thinking activated by performance	
3	High Value of Communication Skills	High value of communication skills
4	Intercultural Competences	Leadership Competences: Coordination and cooperation based on communication
5	Mutual Learning, Understanding and Self-Empowerment	Mutual Learning, Understanding and Thinking outside the Box
	S 3- Social Commitment	
6	Close network to Real Life Experience/Participation in Processes	Social responsibility and practical application of knowledge and skills
	S4- Ethical Commitment	
7	Change of Mind	Development of a sustainable/responsible attitude

5. Implications for Real Estate Education – The What?

Using the four competence groups, the requirements of the stakeholders mentioned above can be described and concretized for sustainable real estate education as follows:

5.1 Holistic Approach

The holistic approach is mentioned in almost every paper, and holistic understanding is one of the most cited skills [50], even though the connotation can differ. For sustainability, the understanding of a holistic approach includes the three pillars of ecological, social and economic perspectives [51], [52], [53]. The empirical findings for real estate education show that reinforcing a holistic approach means integrating ecological, sociologic and urban planning aspects with architecture and technical issues as well as economic considerations, as can be seen in the answers to open questions of the survey. A holistic understanding (also formulated as *holistic thinking, holistic valuation of a situation, bridging to holistic planning* and *holistic stakeholder-management)* is therefore congruent with having knowledge of and being able to integrate all areas of the perspectives model.

5.2 Complex Interrelations

Typical for sustainable topics is a cross-linked content, which cannot always be reduced to a single problem [54]. Therefore, transdisciplinary skills are needed to "cross disciplines, cultures and institutions, to be utilized by the citizens and the professionals of today and tomorrow" [55]. Complex interrelations in real estate education need to be taught not only in *market interrelations* (interview with asset manager) but also in the *economic interrelation within the property life cycle* (industry survey) and *all facets of the property in general* (interview with a corporate real estate manager). Critical reflection of issues instead of simply accepting a situation was required from professors, which would be useless without also taking efforts and being capable to solve those complex problems.

5.3 High Value of Communication Skills

To understand the language of others is one aspect of mutual learning [57]. This not only includes foreign languages, but also the ability to understand specific knowledge, typical terms, connotations and experience in other disciplines [57]. In our interviews, the metaphor of translation between disciplines was used frequently. A CEO of an international asset management company, representatively for the industry regardless of sector and size, formulated the requirement "*to understand the language of all people participating in the property, especially the users' as non-experts.*" Communication skills were seen as most important by all participants of a high-level workshop, just like analytical problem-solving mentioned before.

5.4 Intercultural Competences

In sustainable development, intercultural competencies are in demand because diversity amongst cultures, races, religions, ethnic groups, geographic and intergenerational populations is an issue [58]. In real estate education, intercultural competences are called for as well, e.g. in the *need for discussion of sociological and ethical topics against the background of internationalization and globalization* (student survey). An important skill in this context is to *relieve biases and propose solutions that are compatible to different value systems* (interview with a lecturer), especially in interdisciplinary discussions. According to Nicolescu [59], this skill is an important part of "learning to do" and *communicating on equal footing* (interview with an asset manager). These leadership competencies are especially requested by the industry. Leadership in this context is understood as developing environments conducive for cooperation and target achievement.

5.5 Mutual Learning, Understanding and Self-Empowerment

In a transdisciplinary education program, the mutual learning and understanding of the others' discipline-specific language is the first essential condition for a successful interlinking of disciplines [60]. As a counterpart of the Triple-Bottom-Line-Reporting, the inquiry of the real estate industry results in the need for a *critical research of different methods in feasibility studies* with a focus on integrating alternative methods into traditional monetary valuations. In regards to understanding and empowerment, it was often mentioned that companies do not use appropriate *leadership* approaches. New attitudes are expected, specifically in conflictual projects, but generally due to changing preferences of the new generations. Mutual learning of other (associated) disciplines, flexibility and thinking outside the box are necessary behaviors and skills.

5.6 Close Network to Real Life Experience

The relevance of real life experience in sustainable development has often been illustrated [61], [62], [63]. Garvey [64] emphasized a particular need for personal experience to better differentiate between subjective and objective impressions. The real estate education also asks for practical application of knowledge and skills, e.g. calls for *analyses of financing concepts for sustainable projects* (interview with a lecturer) and strongly appreciates the idea of *student trainees developing more responsibility and needs to intensify research* (interview with a middle-sized property manager). Generally, real life experience is supported by the real estate industry looking for well-educated graduates who are able to act socially responsible.

5.7 Change of Mind / Attitude

The change of mind from “short term evaluation” to “prevention of negative consequences in our acting for future generations” (World Commission on Environment and Development 1987,[65]) is the core issue in sustainable development. Therefore, it should become a concerted and committed focus within universities [66]. It has been shown that strong international efforts such as the declaration of the United Nations Principle for Responsible Management Education (PREM) increased the number of sustainability courses in business schools [67], [68]. But it was also criticized that sustainability courses are often isolated, thus degrading their importance. Real estate education has been dominated by monetary evaluation. Sustainability, however, requires the integration of various non-monetary aspects. Therefore, several interviewees in the real estate industries confirmed the need to teach a *sustainable attitude* that is integrated in the majority of courses, instead of only requiring one specific course on sustainability.

6. Implications for Real Estate Education – The How?

Because of its interrelations and complexity, teaching the *What* of sustainable real estate education is not trivial. As it does not only cover knowledge, but also complex competencies, traditional education methods will not work. In order to develop a curriculum for a real estate Master's program focusing on sustainability, proven didactic concepts from the sustainable development have to be investigated and applied where adequate.

6.1 To use Problem-Oriented Learning

Making students work for topics in groups outside of the classroom allows more time for clarifications and discussions during the “lecture” time. The problem-oriented / problem-based learning supports critical thinking through multi-perspective discussions and the development of self-efficacy [69]. Savin-Baden [70] illustrates that this method efficiently combines the attainment of specific knowledge with interdisciplinary understanding and relevant competencies. The method is thus advantageous for cross-discipline, mutual learning. The crossing of disciplines can occur on the level of different lecturers during the course, between the lecturer and the students, and between the students themselves. In real estate education, Andersen et. al [71] identified positive effects of this method in the students' beginning phase as well as in the phase of compact knowledge building during specialization modules.

Problem-oriented learning fosters a sustainable attitude in real estate because exemplary questions from multiple areas of the industry are analyzed from different perspectives, especially when worked on in heterogeneous teams. The concept deviates from currently existing real estate education concepts as a wide range of "principles" is identified by the students to solve the problems posed instead of trying to transfer "full knowledge" or "ready to use" solutions. This approach helps improving the mutual linguistics as well as the competencies necessary to deal with "new" questions.

6.2 To Cross Disciplines in the Learning Process

Cross-disciplinary learning is an important method to reduce overestimation of the core discipline and to learn from each other in addition to only learning from a teacher or the literature. As Byrne [72] described, a wide range of academic backgrounds has a positive impact on promoting diversity and therefore supports a multi-perspective understanding [73]. For the sustainable real estate program, the authors therefore recommend an equal distribution of study places to three groups, business, engineering and (urban and architectural) planning, because those groups mutually represent the main perspectives of the multi-perspective model. In a cross-discipline learning environment, all students learn to understand (and partly to speak) the specific disciplinary languages as well as methods and conventions of other real estate disciplines.

6.3 To Integrate Real Life Projects

In 2001, Lim already described the importance of real life projects. She found that in the rapid process of human expectations and changing standards of living, real life projects are helpful for political decision-making as well as for reflective teaching. Chapman [74] shows that real life projects help overcoming problems caused by instruments, approaches, spatial and temporal scales that are different in involved disciplines, using mutual goals that align the different interests and views. But the most important aspect of real life projects is the immediate response to own actions and interests [75].

Von Paumgartten [76] recommends the use of flagship examples, e.g. high-performance green buildings in order to change "the way businesses look at their portfolio of facility assets". Accordingly, some industry interviewees suggested to develop feasible and lucrative examples of sustainable real assets. However, flagship projects entail the risk of not being transferable to bread-and-butter projects, therefore "normal" as well as non-performing projects should be presented and worked on as well. In real estate education, in programs of architecture, urban planning and construction engineering, real life projects have been common and highly accepted, which facilitates a respective implementation in a transdisciplinary program. In such programs, it is furthermore advantageous to team up students with different backgrounds to prevent a single disciplinary perspective on the real life problem.

In the new Master's curriculum, a larger real life project, e.g. the development or redevelopment of a property or the development of a neighborhood, challenges the students at the end of their studies. Because such projects cover all perspectives of real estate, students get the opportunity to test their interdisciplinary knowledge and integration competencies as well as their soft skills acquired so far thus making these projects an important milestone before graduation.

6.4 To Substantiate Theory by External Experts and Field Trips

The tremendous relevance of in situ professional and stakeholder education is described for several institutions [77], [78], among them the Master's program Sustainable Development at the University of Basel. The collaboration with external experts supports the students during the whole interdisciplinary program. A characteristic for the real estate industry and its parts is the rapid change in local specific knowledge which often leads to professionals' selfishness where knowledge is treated as a value object and not shared voluntarily. This conflicts with holistic approaches where sharing of knowledge is a major prerequisite [79]. Sharing of knowledge between students does not suffice; in addition, external knowledge of experts should be integrated into the program. To encourage networking, knowledge sharing and discussions, the authors embedded field trips, real life project work and external experts teaching sessions in class.

6.5 To Confront Transdisciplinary and Disciplinary Students with Each Other

It can be supposed that students who apply to a transdisciplinary program are interested in and open to the multiple persepctives of real estate. When mingling those students with students of the 'pure' perspectives and representing traditional views, the learning experience for both groups will further be leveraged as this confrontation anticipates the later real life situation. It increases awareness and respect for alternative knowledge and attitudes, and fosters respective understanding that is central for the future cooperation on real estate issues. Another recommendation for a sustainable real estate program is therefore to design modules in a way that makes them accessible to students from disciplinary as well as from transdisciplinary programs.

7. Discussion and Final Comments

Based on the *What* and the *How* described above, the concept for a sustainable real estate Master's program in Germany was developed. The program is intended to be studied full-time – at least in the first two of four semesters. While this deviates from the vast majority of existing real estate programs in Germany, it seems to be necessary to cover the broad range of knowledge areas, to use the proposed didactics, and to foster the intended university level research orientation. As a heterogeneous student body, including planning, engineering, and business knowledge, is a major preliminary for the program's success, admission rules for an equal share of all three were defined accordingly. In the first two semesters of the program, "principles" of all three areas are to be explored and applied in a problem-oriented learning setting. Modules of project management and project development provide the theoretical foundation as well as application opportunities. In the second year, students may choose from existing and newly created modules that allow them to specialize on a perspective; specialization, however, does not mean blocking out other perspectives, but to focus on certain topics while still applying a holistic approach. The vast majority of modules offered was designed together with faculty from 'pure' perspectives, is open to and integrated into other Master's programs, and is correspondingly taught by a multitude of faculty members, supported by industry members. Those may also provide cases and data. Real life experience is furthermore made accessible through applied projects in each of the four semesters.

The concept faces at least the following two challenges: Firstly, today's higher education is dominated by lecturers who are experts in their fields and used to working independently. In contrast, the proposed holistic approach requires cooperation in designing and teaching modules. This results in more coordination and thus time needed which is mostly not accounted for officially. Secondly, holistic approaches need a specific attitude, an openness to understand and integrate others' experiences and opinions. As a consequence, many do neither appreciate nor support a holistic approach, which makes implementing such a program a serious challenge.

8. Conclusion

The complexity of real estate and its large impact on sustainability requires specialists as well as generalists, with the latter being experts in combining holistic knowledge of real estate with leadership, communication and coordination skills. Sustainable real estate programs should therefore provide students with interdisciplinary knowledge and skills that allow them to find sustainable solutions together. Research on Master's programs in sustainability identified four core competence groups: systemic and critical thinking, anticipative thinking, social commitment, and ethical commitment. An empirical study with surveys and interviews among real estate practitioners, teachers and students showed many similarities between sustainable development and sustainable real estate justifying the approach to adapt recommendations for higher education in sustainability to the design of real estate education. Hence, real estate Master's programs should employ a holistic real estate perspectives approach, stimulate critical reflection of real estate issues, foster leadership competencies – especially communication and coordination skills –, encourage transdisciplinary learning and develop a responsible attitude for the broad variety of real estate matters. Furthermore, didactic methodologies from sustainability education, such as problem-based and cross-disciplinary learning, real life projects and the integration of experts and field trips, can be applied successfully to real estate education.

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SUSTAINABLE RE-USE OF A BUILDING IN THE CASE OF CULTURAL INDUSTRIES: 'SALT GALATA' ON VOYVODA STREET IN ISTANBUL

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Summary

Main interest of this research is 'use value' that refers to the public image. In this study re-use of a building is going to be analyzed in terms of sustainability. In the process of time, 'building' becomes 'devaluated'. Its level of productivity goes down and need of renovation arises. 'SALT Galata Cultural Institute', the former Ottoman Bank of 19th century, one of the most important architectural forms of capitalism of the Ottoman Empire, is going to be introduced as the architectural case. This paper attempts to make a contribution to limited urban studies about Voyvoda Street since it is not as much exotic as the other areas in Istanbul with its architecture of Modern West [8]. It will begin by reviewing how Bank has transformed into a Cultural Institute and finally the contribution of use value will be discussed to sustain critical thinking of architecture as an urban culture. Exploratory case study structured through interviews and observations along street. It is important to underline that most of the old photos are having Ottoman Bank building as a focal point as an architectural reference of the street. This phenomenon makes the building a landmark which has sustained its legibility by variety of urban images over a century and the research is questioning how SALT Architecture as an image of Voyvoda sustains urban culture.

Keywords: Architecture, Landmark, Use Value, Urban Culture

1. Introduction

SALT is located in Istanbul, Galata Region on Voyvoda Street. Voyvoda is an historical route of financial activities and synthesis of urban culture of eastern user profile and western style buildings [8]. Research is being limited to the building and its microenvironment of Voyvoda whereas colorful urban life consists of stock exchange, harbor, casino, call house, taverns, etc. and this complex life of Galata won't be discussed to avoid research to get dispersed.

After restoration of the former Ottoman Bank, 'Money' issue has transformed into production of Culture; in other words cultural industries. SALT Galata is re-organized to enable a multi-layered program which makes it a center of attraction for public. It offers public access to Auditorium; Museum; an Archive and Library; an exhibition space; a Café and Bookstore [20]. Restoration is financed by a multi-national corporation called Garanti which is one of the biggest financial institutions of Turkey [19].

Architecture has thus been the quintessentially universalistic expression of civilization and reflection of culture [3]. Architecture as an image of urban culture should be sustainable because it is an evaluative process of perception. Use of architecture is a value, which creates a ground for critical thinking that needs to be a sustainable social and cultural practice of community. Culture as ". . .a complex web of relationships and beliefs, values and motivations. It is a social operating system that influences attitudes, behavior and responses to change. This system operates on personal and communal levels and may be a barrier to, or a catalyst for, the development of social capital” [11].

From 19th century on, building has been a landmark, which is referring to an architectural reference point in an area, which can be either symbolic or physical. Cultural industry is used as a common concept of cultural and creative activities and this heterogeneous group of industries comprises the cultural or the creative economy [2] as ‘an integrated sector’ of theatre, the visual arts, music or filmmaking or design and fashion. Creative artists often work across different cultural fields [25]. The head office building of Ottoman Bank and todays’ SALT is symbolic in more than a way; it was matching the prestige of the bank in magnificence and also the first modern bank building of the period, and, as such, initiated a new architectural function and design, which would soon prevail in the city, particularly on Voyvoda Street [17].

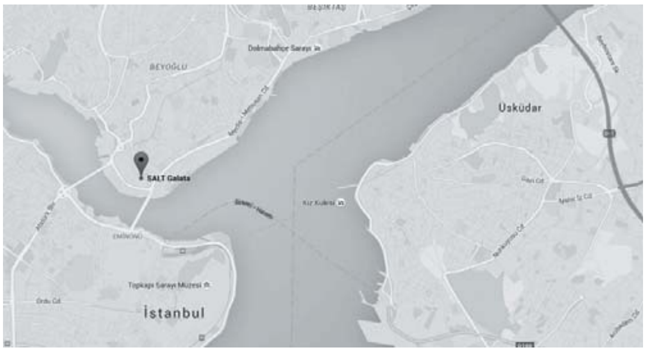

Fig. 1 SALT Galata Location Map Source: google.map

The claim is; architectural landmark has to be sustained as a cultural practice of community and an image of urban culture. Sustainability is widely accepted as an important conceptual framework (Williams et al., 2000) where one of the main sources of disagreement within the debate about sustainable development is what is to be sustained [6]. Sustainable development as a concept was developed alongside acute awareness that the ecological destruction and the 1980s ‘retreat from social concerns’ – manifested as poverty, deprivation and urban dereliction that blight many parts of the world – are untenable [5]. It covers a wide range of issues; choosing and sourcing materials, the amount of energy needed to transport and finish them, building construction processes, durability, internal flexibility in terms of use, adaptability to new technologies in the supply, the use of solar energy for the purposes of heating, cooling, using daylight and generating electricity [18]. The City Form research group defines urban sustainability in relation to social life, economics, ecology, energy and transport. In such holistic examinations of sustainability, care must be taken to ensure that concepts underpinning the definition of social sustainability retain integrity and coherence in relation to the overarching understanding of urban sustainability [6].

2. Methodology

Originally, this paper is based on a doctoral study of historical research of 120 years back and exploratory case structured through two interviews with the dominant actors of the street; retailers, about SALT within its environment that is referring to building’s closest surrounding of 50 meters of each sides of street. Also press reviews carried out after 2011 has browsed. It is important to underline the difficulty in obtaining data during historical research that photographic archive of the Street is not broad and most of the old photos are having Ottoman Bank building as a focal point. This gives an idea about the building as being one of the most important architectural references, which is called landmark and main guidance of urban study of street.

3. Historical Background of Landmark

``One can say that the city itself is the collective memory of its people, and like the memory it is associated with objects and places. The city is the locus of the collective memory. This relationship between the locus and the citizenry then becomes the city's predominant image, both of architecture and of landscape, and as certain artefacts become part of its memory, new ones emerge. In this entirely positive sense great ideas flow through the history of the city and give shape to it. Thus the union between the past and the future exists in the very idea of the city that it flows through, in the same way that memory flows through the life of a person; and always, in order to be realized, this idea must not only shape but be shaped by reality" (1982, page 130). [19] [10].

The project of an 'Ottoman Bank' was born in the minds of two British entrepreneurs in search of a niche in the still underdeveloped commercial banking sector of the Ottoman Empire. Upon receiving Queen Victoria's royal charter on 24 May, 1856, the Ottoman Bank was established with a capital of 500,000 pound. For some eighty years from its establishment in 1856 to the 1930s, the Ottoman Bank has been at the center of the rapid political and socioeconomic changes witnessed from the Tanzimat reforms to the Republic [7], [17].

Ulrich Beck asserts that 'architecture is politics with bricks and mortar' (1998:115) and undoubtedly from the perspective of social theory we can see that architecture has an important role to play in the shaping of social and political imaginations [3].

Practices introduced by new administrations very often bring about changes in the architecture of that particular country and the appearance of its cities. The change may be displayed in architectural forms, stylistic features, construction techniques, materials employed or even in large urban layouts. The Ottoman sultans, particularly in the classical period, would find self-expression in the architectural domain by the construction of monumental complexes. The Tanzimat, together with the events that immediately preceded and succeeded it, is a phenomenon that requires very careful examination as a most important step in the history of reform in Turkey, with the architecture of the period playing an extremely important role in a proper understanding of the period [3]. Tanzimat was a period of change based on European models and twenty years of Tanzimat period was dominated by foreign architects and Ottoman Bank Galata Head Office was one of these projections. Symmetrical axial layouts were generally preferred in the facades and façade decoration became more ornate, with sculptured columns and precast facade elements [3], [12].

Building defined as landmark because building has always been a focal point of area as it has been found during research. The contents of the city image have been studied by Kevin Lynch in 1960. He has defined city with five contents of edges, nodes, districts, paths and landmark. Landmark is a term which is described as type of point reference which is external, observer doesn't enter within. They are usually simply defined physical object; building, sign, store or mountain [15]. Some landmarks are seen from many angles over the tops of small elements like isolated towers or great hills whereas other landmarks are primarily local and visible from certain approaches. They are used as clues of identity and they may have historical, cultural or economical identities.

Fig. 2 Ottoman Bank 19th cc, SALT Galata 21st cc and Voyvoda Source: History of The Ottoman Bank, Ottoman Bank Archives and Research Center, 1988; saltonline.org; Serengül Seçmen, 2015.

When there were no banks around 1880s, tradesmen and bankers were the most important employers. During that period, the khans were being called with their owner's names. When construction boom has been launched meanwhile infrastructure has been repaired and new types of building styles with their names referring to the company were introduced. So, it is a launch of capitalism [8] and phenomenological symbolization. Ottoman Bank Building was such kind of landmark of old times and today.

3.1. Chronological Milestones of Building

Voyvoda, Bank Street, is not an ordinary street. It has always played a central role in the life of the district of Galata. In the second half of the nineteenth century Voyvoda Street acquired a totally new identity, as a center not only of Galata, but also of Istanbul. One of the most striking aspects of Voyvoda Street was its close connection with the economic and financial life of the Ottoman Empire, with respect to modernization, which was reflected both in the business profile and the architectural outlook of the street. On this three hundred meters long street, lay the financial heart of the empire [8]. Building exists over a century and it has a detailed historical aspects. Chronology is being specified along with distinctive years which are named as milestones in case to make a brief description of its use evolution. All data written below has been collected from the Ottoman Bank Museum permanent exhibition, which is located in the SALT Galata.

1856-1863: Ottoman Bank established by 'British' entrepreneurs and became a 'private' commercial bank.

1890-1892: The establishment of a state bank was considered by Ottoman Empire and Ottoman Bank had been declared as being one of the most experienced one. The bank is renamed as 'Imperial Ottoman Bank' since imperial and European financial resources has been merged.

1892-1998: The outdated structure of bank could no longer meet the bank's growing needs and rising image. A new head Office building has been built on Voyvoda as symbolizing modernity and prestige.

1914-1919: During that period because of the war and the ideological Turkish revolutions Bank has stopped its operations with the enemy side of England and France.

1926-1931: The Imperial Ottoman Bank's foreign name, identity and autonomy has been criticized during the process of Imperial's falling down. 'Imperial' has been removed from its official name and by the establishment of 'Central Bank' in 1931, it has lost its official titles. The Ottoman Bank had been able to maintain for 68 years more as a private bank.

1996-2001: It was acquired by Doğuş Group in 1996 and merged with Garanti Bank in 2001 [17].

2010: Garanti Bank has been merged with another Spanish Partner and became a private partnership bank. During that period, it became one of the strongest in the financial sector and reinstutionalized [23], [21].

2011: The former bank building has been turned into a cultural institution by Garanti Bank and became one of the institutionalized cultural public spaces.

3.2. Architectural Background of The Symbol of The Bank: Galata Head Office

Architecture plays an increasingly ambivalent role in the state project today. In the past architecture had a central role in creating and codifying national cultures, with states often using landmark buildings to reflect national identity and historical narrative of memory. The great buildings of the period 1850 to 1914 testified to the self-confidence of the nation-states and imperial powers that often used buildings to give tangible form to abstract values. Architecture was central to the cultural self-understanding of the nation-state in modernity, as is best illustrated by the Haussmanization of Paris (see also Jones, 2003) [3].

Fig. 3 Ottoman Bank and SALT Interior Photos Source: History of The Ottoman Bank, Ottoman Bank Archives and Research Center, 1988; Serengül Seçmen, 2015

The building has distinct architectural styles-neoclassical and oriental-applied on opposite façades [20]. The front façade on Voyvoda Street and facing the ‘western’ districts of Galata and Pera, reflected a neo-classical or neo-Renaissance style, quite consistent with the majestic and soleman attitude displayed by most European bank buildings of the nineteenth century. However, its rear façade looming over the backstreets of Tower Galata, and facing the old Istanbul lying beyond the Golden Horn, have traces of neo-Orientalist style for which Vallauri had often shown great interest. This conscious contrast between the two facades, spoke of the position of the bank between East and West, and carried this message into the urban context [17]. So, the architecture is an east-west synthesis and it is a concrete symbol of Europe and Ottoman Partnership.

3.3. Ottoman Bank Staff and Customers in History

Information of bank staff and customers that was stored which gives clues about the social profile. In the personnel files of Bank, full-body photograph that was required from each employee is the most interesting information stored. Physical appearance, body gesture, costume were a wide range of phenomena from self-image of hierarchical power and submission [17].

Another historical detail is that staff ethnicity range was mostly local non-Muslims like Jewish, Rum and Armenian is a result of being an English Entrepreneur Employer. It is expected that Galata has turned into a westernized financial center, especially when it is considered that Galata bankers, which is not a famous phenomenon of today among Street users, since Bankers are the most important social background profile, who were in contact with the European financial centers.

Fig. 4 Ottoman Bank Personnel and Staff in History Source: The Imperial Ottoman Bank, Ottoman Bank Archives and Research Center, 2002

Customers’ files also show that mostly local non-Muslim burghers were forming the profile. Generally, it can be assumed that social topography of the environment was under command of local non-Muslim community. Government and public authorities were under administration of

Muslim community whereas in financial activities non-Muslim were the only partners [22]. Architecture of Modern West has fit with westernized urban culture that makes it not only a landmark but also a use value.

At 50s the need of technology had given rise and many of the former professions were gained importance and Electronics market had been started to grow. That was launched the economic revitalization of the Street through electric supply retail and out immigration of non-Muslim Galata community was exchanged with the mass migration from East of Turkey. In this case, socio-economic profile has changed in a short period of time [8]. At 90s another axis called Levent-Maslak was formed as Central Business District and along with that, administrative functions of financial companies were moved to there and left behind unimportant departments in Voyvoda [8].

Galata was the financial center and harbor district of Istanbul at old times and Voyvoda was a multi-cultural urban context. Lately, private art institutions those are located in Beyoğlu district has pulled into a process of institutionalization and SALT is one of the best examples of it as being a model of a bank which has used culture as a tool of investment. Today, Galata sustains its multi-cultural life not with finance but mostly with art and service.

4. Site Survey

4.1. Observation Notes

Observation has been done during daytime for two days at different hours. Variety of behavior has been recorded as the main factors of street's environment. What keep the Street alive is the electrical supply service activities of retailers beside accommodation service of hotels and SALT.

Even it is not wide common positions to stand outside, electrical supply men and rarely women stand or sit right outside the shops to spend time. Sitting on a chair or over bended knees are the common positions of that act. It is common that security men standing outside the doors. These are the static behaviors but the dynamic ones are mostly containing people with electrical supply packages bought from the shops or porters carrying packed good along the street from one place to another or from truck to shop. While construction workers are trying to fix a metal form of a restoration of another hotel project, a tourist is walking through and looking for SALT and meanwhile another tourist is coming down from the historical stairs heading towards to SALT. Pavements are not used by visitors of SALT as a foyer because of SALT having an interior courtyard for this purpose. So, it is not easy to detect how many people are inside, beside its architecture doesn't let interior be visible.

Fig. 5 Location of SALT and Ground Floor Use on Voyvoda Source:Elife Bilgin Dinç, 2012

Fig. 6 Behavioral Scheme Photos Source: Serengül Seçmen, 2015

4.2. Press Notes

In the 2000s, modern art institutions have flourished in the city. New museums have been created, new art galleries have emerged, biennials and art fairs have attracted a growing number of visitors, consumers and art merchants, and many new projects are still under development [15].

International and national articles have been browsed online but data was very limited. The most interesting is from [9], which is written by Suzy Hansen. It contains some interview notes of Turkish artists and writer's self-conception.

Hansen starts her article with an interesting self-determination; ''The giant 120-year-old Ottoman bank building in Istanbul reopened as a multimillion-dollar contemporary art space called SALT. This was surprising. Turks were never big on contemporary art, and for years rich people didn't visit that part of town. When I moved to the neighborhood girlfriends wouldn't visit after dark; a neighbor once attacked another neighbor with a small sword. I don't see swords in Istanbul anymore. I do see a lot more art.'' But she names that as an art-boom bubble which can be said that it is not sustainable, one day bubble is going to blow out.

''At SALT's opening, as we stood in the gorgeous library full of art journals and magazines and books, a European friend wondered why they'd built a library in a space for exhibitions. It's because there aren't many libraries to be found.''

''It appears that Istanbul, which went from a cosmopolitan wonderland in the 19th century to, in the Nobel-winning novelist Orhan Pamuk's words, a "pale, poor, second-class imitation of a Western city" for much of the 20th, is having its moment of rebirth. These newly wealthy corners of the East seem full of possibilities, but what kind of culture will the Turks create?''

SALT as a container of art and culture provides space for community to be more creative but on the other hand loss of certain buildings or spaces in the city as a result of urban growth overlaps with experiences of personal loss, so that the new architecture in the city ironically acts as aides-memoires of the drastic shifts in subjective history [13]. It is clear that architecture is not only responsible for shaping collective memories but also provides a cultural potential for the expression of new identities. As such, architecture can be an important space for the reflection and creation of reflexive post-national identities. There is perhaps a suggestion that some landmark architecture has come to be a metaphor for the society in which it exists [3].

4.3. Interview Notes

As it has been mentioned, electrical supply is the dominant commercial activity and there are two types of activity; retail and import. According to that, retail stores serve as small scale supply and face to face customer sales whereas import is a much bigger activity needs no direct customer interaction. Though these supply companies are not in need of street store, they are still in need of service door for medium scale packages, storage and administrative offices.

Interviews have been done with company owners.

Interview 1: Fabrik Elektrik Ltd./ Commerce Type: Retail/ Store Possession: Rental

-Galata is an historical area, consequently it has been always a center of attraction for tourists whereas Voyvoda has been a financial activity route and has never been as much attractive as the rest of the area. Last decade many of the buildings has been started to transform into hotels and nowadays we see tourists more than ever before on Voyvoda. What are your concerns about that situation?

- ''Area is a World Heritage Site that is approved by UNESCO and after the declaration of Galataport Urban Regeneration Project of Galata Harbor many buildings have been started to transform into hotels. These hotels are not luxurious or high price ones but serve to tourists around 60 euros per night. Since this area is a multi-national area, there are many buildings those are belong to companies of other nations, big scale urban regeneration project is not an applicable process. So, transformation is proceeding within building scale not in area scale. It has been a long way, around 20 years, since that process has been launched and has not been completed yet. 20 years ago a central building for electrical supply called PERPA has been designed in another district to make those stores to move but most of the retail stores didn't prefer to leave. There are some reasons of not leaving but most important one is it wasn't a bulk movement. Still we are aware of transformation and we are going to leave or stop retail activity someday.'' Consciously, they are going to leave and they are not insisting on not to leave. It can be said that it is because of slow transformation.

-SALT could have been a hotel also instead of being a non-profit institute. Why do you think that it was not preferred to be designed as a hotel?

''After building has been bought Ottoman Bank, whole property of the company have been transferred to Garanti Bank company. Yes, institute could have been preferred to design it as a hotel but cultural institute is much more prestigious investment than a hotel. There are many medium price hotels around area and it is a fixed value, not for an international corporate. SALT doesn't have any impact on that process of transformation; it is just a value for public use or an element of that process of time or a need both for Istanbul and Galata. My son, he also uses its free research center and says that it is used by many people densely. Many times it is full and it is not easy to find a space to sit and study or read. Once, me and my partner we had a dinner on top roof restaurant and we have paid a lot of money. It is a high-price one. Adjacent building to SALT is used to belong to Generali Securitas and they have sold it and now it is being designed as a hotel. ''It seems as a prestigious investment and public value. Even they have visited SALT more than once not only tourists. He adds as final words; ''Voyvoda is an international land and government is not able to make direct attempts over it.''

Interview 2: İletim Elektrik A.Ş./ Commerce Type: Import/ Store Possession: Owner

-Previous twenty years the disintegration of electric supply sector on Voyvoda has been declared as a policy. In this case a vast building complex that is called PERPA has been built to house industrial retail shops. It seems like you haven't moved to PERPA? What is the reason that keeps you on Voyvoda still today?

-''We haven't moved because we are the owner of that building and we have already another store in PERPA. Actually we are not planning to turn it into a hotel but we are flexible for the changes and we are happy about the touristic changes of area. It used to be not safe to stay here at night but now it is much safer than before. We don't hesitate to stay until late hours or it is not frightening to close the store after 8 pm in the evening. You can see a woman running with her tight pants, before this street was not for women to walk because of heavy eyes of men. ‘’The building is much more valuable than before. The price is around million dollars.

- SALT could have been a hotel also instead of being a non-profit institute. Why do you think that it was not preferred to be designed as a hotel?

-‘’There are many hotels in the area and going to be. Why another hotel? SALT is an important distinctive venue for tourists in the area. ’’ He thinks that it is a museum for tourists to visit.-‘’SALT has no impact on this transformation, it is an architectural result of it.’’ Since SALT does not have a distinctive architecture, differs from the other western style buildings of the street, more than an assertive position it seems modest and open-minded.

Descriptive output of interviews is that electrical-supply sector is going to move and they are not insisting on not to leave as a result of slow transformation of the area. SALT is seen as a prestigious investment and public value both for electrical supply sector since they have also visited SALT more than once. However SALT does not have a distinctive whereas bulk architecture, is not an assertive but a symbolic landmark and has a modest image on minds of retailers.

4.4. Economic Growth, Social Inclusion and Physical Protection

Landmark is protected architecturally and gained its liveable ground again. This has sustained physical entity and its public function has provided social inclusion of diverse groups. Social and physical legs are completed with economical growth, which creates the trivet model of SALTs' sustainable re-use. Even if the buildings' evolution is not a part of a regeneration policy, it can be promoted as an unprogrammed model for further studies which intents to become a socio-economic incubator of sustainable regeneration of the street. Since SALT is the single type of function on the street, it promotes a ground for mixed-use developments and delivers the initial scheme for cultural industries as a tool for economic sustainability of the street. Even if the institution is non-profit, it is able to afford its expenses by rental incomes of seminar rooms and art exhibitions hence its value has not been unbalanced by a rise in exchange rate. It creates an innovative service approach, which is new to the street, and it is a bridge between two poles of economical environment; accommodation and electrical supply. Building might have been a needed element to balance the trivet model of sustainability of the street and further studies can concern if the street is becoming a space based on cultural activities, which is rather different than electric supply cluster. In economic terms, this means that within an industrial cultural district the costs of the use of the market are lower than anywhere else because of the intense creation of positive externalities, tacit knowledge, the high rate of innovation, easy networking and the cost-free diffusion of information [24].

5. Conclusion

As being a cultural industry space, SALT is a landmark of cultural activities. Yet its architecture has never been distinctive along street, it has always been a landmark for financial purposes in history, but today it has variety of image. Evolution of the building shows that being private bank, then national bank and finally SALT that has formed different types of use value. For Ottoman Bank staff or customers; it used to be a financial landmark whereas for retailers; also a prestige landmark; on the other hand for researchers, tourists, intellectuals visiting art gallery it might be an art and culture landmark. Considering these entire multiple image of 120 years period of time, nothing like SALT exists in Istanbul. It might be not wrong to assume that it will be the one and only in the future just as it is today since most of the buildings are transforming into hotel. Sustainability considers not only physical environment, but also economic and social dimensions. SALT Architecture is a multilayered image of urban culture of Voyvoda which has to be sustained to create a ground for experimental thinking as a cultural practice of community. Head office of old times has evolved into another head function of street but without losing its previous image of Tanzimat; concrete image of Europe and Ottoman partnership. Interaction between different classes and nationalities has never stopped. SALT is an initial cultural space among area and opened a way for discovery of the Street apart from hotels. Voyvoda is a multi-national land where national government has not had authority to make direct attempts over it. Sustainable development might be discussing how to sustain a person's livelihood, a development project, a policy, an institution, a business, a society, a community, culture or economic growth and SALT is a product of a cultural value process of street use. It is a trivet model of sustainable re-use and socio-economic incubator of sustainable regeneration of the street. Image of SALT has to be sustained to create a ground for perceptional thinking as a cultural practice of urban community and innovative economic development.

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Sustainable Urbanism: Research-based collaboration of intercultural and transdisciplinary student teams towards resource-efficient solutions for challenges of current urban planning on exemplary neighbourhoods in Hamburg.

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Summary

Sustainable urbanism leads socio-cultural setting and resource-efficient use of materials, water, energy and traffic to a synthesis. Aspects of sustainable urban planning are densification, mixed use, urban sprawl, green technology or human scale neighbourhoods. This can be reached by promoting diverse urban sub-centres, in a so-called polycentric city like Hamburg.

In order to apply this conceptual framework in a comparative way, seven teams of international graduate students proposed solutions on sub-centres in Hamburg, based on an in-depth analysis of those neighbourhoods. Participants have different academic and professional backgrounds in order to be able to analyse, discuss and propose in a broad, interdisciplinary way. Also, they have a diverse cultural background, which constitutes a global understanding with regards to technology, politics, culture and climate.

The aim of this collaboration is to derive strategies for the improvement of livability and sustainability of urban neighbourhoods through extensive communication among diverse perspectives. The presented outcome is based on critical theoretical discussions, case study analysis and contextualised, detailed physical interventions which shall be adapted to other locations in a useful way.

Keywords: Interdisciplinary Planning, Polycentric City, Sustainable Urbanism, Best Practice

1. Introduction

Find out what makes a neighbourhood sustainable and propose measures to make it more sustainable and livable, “to rethink where and how we live, work, play and shop” [1]. Basically, this was the task of a research-based project work at HafenCity University Hamburg (HCU) for 29 international students of the master of science degree programme Resource Efficiency in Architecture and Planning (REAP). But what makes an urban neighbourhood livable? Referring to the fact that more than half of the world's population is now living in urban areas and these areas are consuming 75 per cent of the world's natural resources and 60 to 80 per cent of the global energy production, urban and environmental planning must “apply incremental approaches as well as seeking major economic and social change with strategies that will work, to envisage and apply a new, daring and ambitious environmentalism to radically re-engineer our urban settlements” [2].

Cities need to become more compact and resource-efficient and planning requires “holistic approaches and whole-of-system thinking to deal with the entire 'urban metabolism'" [3].

Intercultural and transdisciplinary work is practical reality in planning, which requires to prepare students as the future decision makers of urban development for that too. The aspect of diverse research, teaching and practise is being integrated into planning principles, in contrast to conventional research and discussion, which tend to forget the reflection of planner’s perspective and background [9]. This paper reports of a one-term, 10 credit points course called Project 2 (P2) in the second term of REAP. It presents major outcome related to traffic, material, water and energy, which serves as an example of how to apply the concept of sustainable neighbourhoods through academic knowledge exchange. We argue that intensive interdisciplinary master's programmes have potential to transform the way Sustainable Urbanism (SU) is being transmitted and applied.

First (Section 2), this paradigm and its major principles will be explained. Section 3 describes the programme and the composition of the groups. Then (Section 4), we will go on with the focus topics the groups dealt with and give an overview of the tools which were used for the analysis and proposals. Section 5 presents remarkable outcome, both for SU and the situation in Hamburg. In the conclusion (Section 6), we will summarize and discuss how the project work may be further applied.

2. Sustainable Urbanism: Concept and Paradigm

The fact that “over half of the world’s population lives in urban areas and this proportion is expected to grow to 67 per cent in 2050” [2], in combination with climate change cause the urgent need for urban planning to set the course for environmentally responsible, socially equitable and economically viable solutions [4].

“The smart growth, new urbanism and green building movements provide the philosophical and practical bones of sustainable urbanism” [1], which is the theoretical context of REAP. It promotes widely agreed principles of how to plan a city in order to make it sustainable, meaning inclusive, resilient, prosperous and ecological. SU is the mainstream paradigm of planning in the late 20th and early 21st century in contrast to modernist planning subsequent to industrialism. Fig. 1 summarises the main principles of SU and resource efficient urban planning along one of the student team’s project aspects in Hamburg.

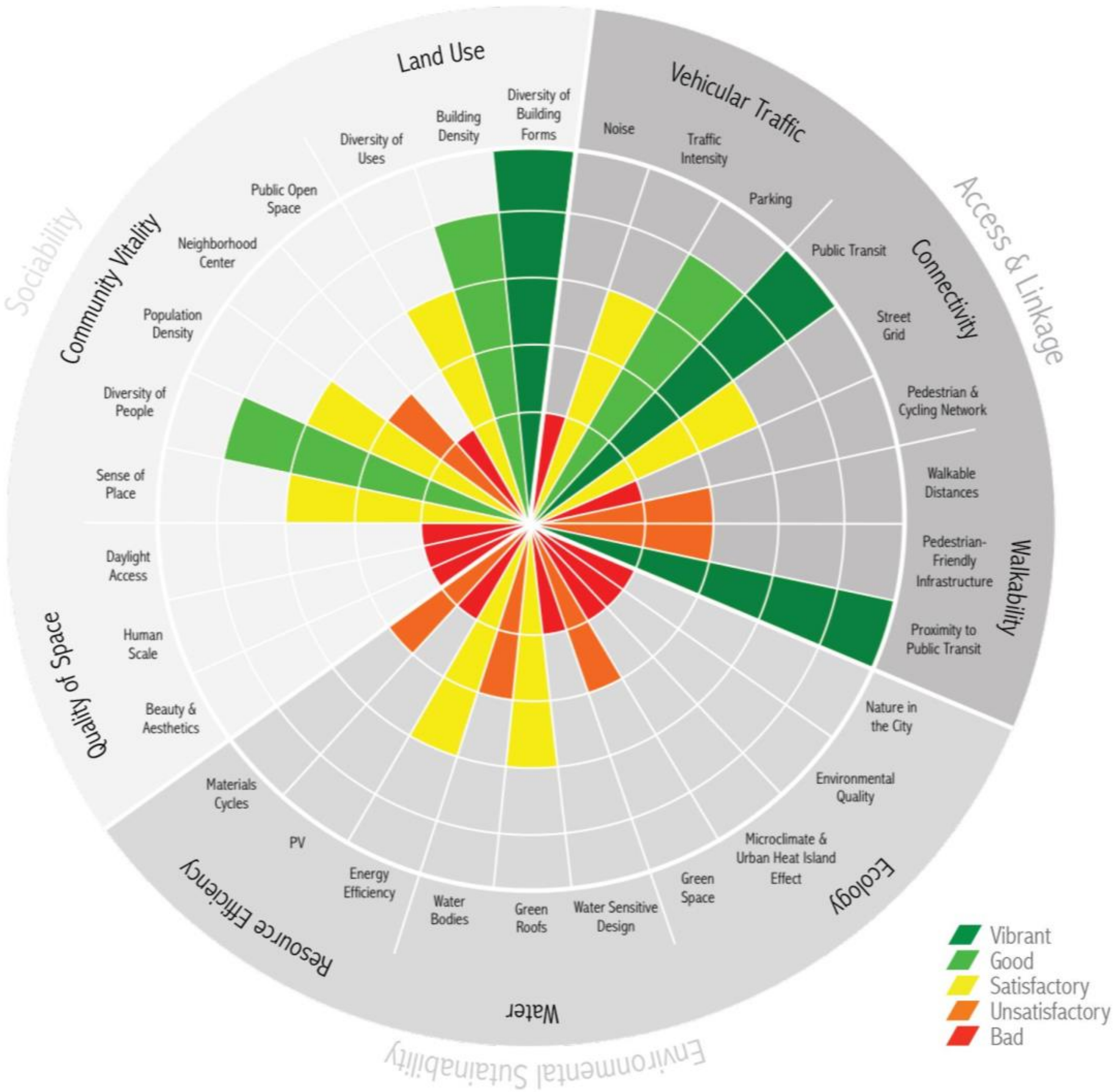


Fig. 1 Multi Criteria Analysis. Source: REAP P1 (Sievert, Schulte, Valladares, Valdenebro)

The so called compact city of high density is polycentric and human-scale with access to nature [1, 4]. This means that there are neighbourhoods within the city which provide diversity in land use and social strata, based on “the idea of the city as a mixing pot for people of different cultural, ethnic and class backgrounds” [2]. The urban layout seeks to minimize the distance “travelled per person per day between workplace, home, school, shops and leisure activities” [6] for better sociability [4] and low-carbon transportation and efficient energy supply (potential reduction of 50% [1]). While accepting urban areas being condensed habitats, SU aims to rehabilitate cities towards natural systems by incorporating green space and natural water cycles. Climate change as one of the drivers of the global sustainability movement influences urban planners with regards to adaptation to changing climatic conditions and its consequences. Embedded in this context, the architectural and engineer’s aim is to provide high-performance buildings and transportation.

According to Moore (2013), this “formation actors, practises and principles” [9] runs the risk of blind transplantation because it does not question its formation and, subsequently, the real challenges. This call for more reflected and contextualised transfer and application of SU can be solved by educating people the way REAP does; this will be subject of the next section.

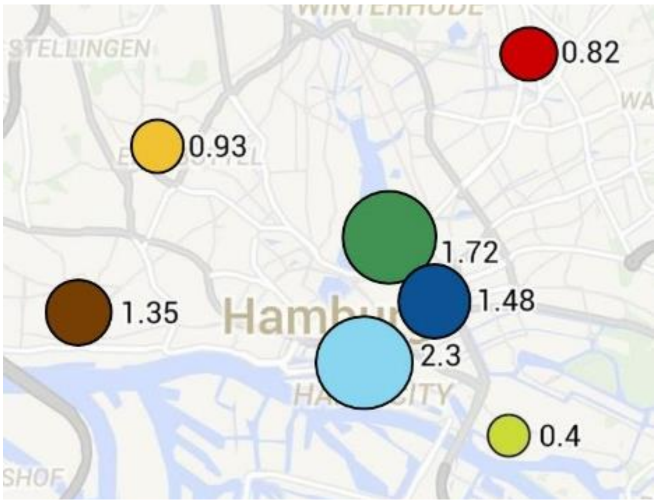
3. The REAP Master Programme and its central Project 2

The application of concepts like human scale design and compact, polycentric cities are interrelated to a complex mix of economic, aesthetic, environmental, social and technical questions and have to be dealt with likewise. This is the aim of REAP, which is intentionally diverse in two different respects: It is inter-disciplinary as it incorporates more than ten different undergraduate and professional backgrounds (engineers, natural and social sciences). This means different conceptual knowledge levels, different approaches of solving problems and different attitude to work and workload. As Bovill (2015) puts it, “architecture like ecology is surrounded and supported by multiple disciplines” [7].

Moreover, the participants come from from four continents and 17 different countries, a condition for cultural and personal diversity. The people have known each other as they study a two years programme together and they know Hamburg as expat residents. Participants formed seven mixed groups of four students and chose a quarter in Hamburg and two out of the focus scopes (SU, Water, Traffic, Energy, Materials). Those scopes are covered by parallel lectures which gave input on the topics and the lecturers were available for expert consulting. In conclusion, the diversity of REAP is not only normative, it rather challenges the participants in various ways during the team projects.

4. Scopes and Methodology

The project was divided into two parts: analysis and proposal. During the first part, the groups used a multi-criteria analysis (Fig. 1) and various indicators to analyse 1000m x 1000m of a neighbourhood. Exemplary for dense urban neighbourhoods, the floor area ratio (FAR) was used to show the relation between gross floor area and site area [8]. In order to decide upon densification measures, FAR shows potential especially in sub-urban quarters of Hamburg (Fig. 2). Another measure related to urban water cycles is infiltration potential in order to evaluate the possibilities of decentralised stormwater management (Fig. 3).



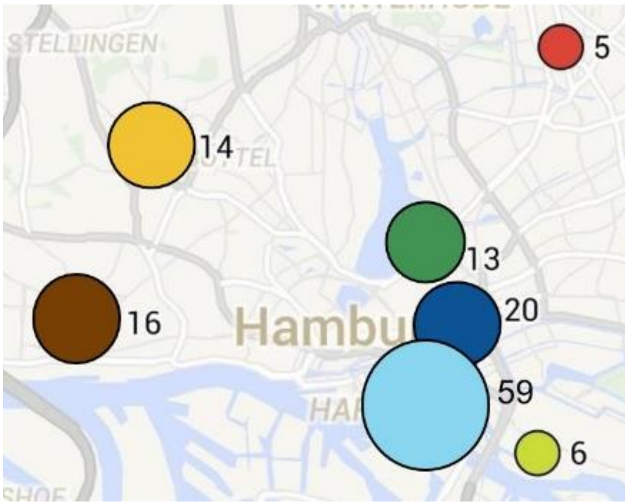


Fig. 2 Floor Area Ratio. Source: Own Compilation based on HCU REAP P2; Google Maps.
Fig. 3 Infiltration Potential [%]. Source: Own Compilation based on HCU REAP P2; Google Maps.

In order to complement water-, energy- and material-cycles as technical scopes with the socio-economic side of urban planning, SU was chosen as a cross-cutting scope by several groups. For them, this widely meant to put physical interventions in a socio-economic context. Gentrification plays a role in some of the quarters, as the rent index (Fig. 4) shows. In order to consider that, the students' proposed financial solutions for implementations, which can contribute to justice in income distribution and participation.

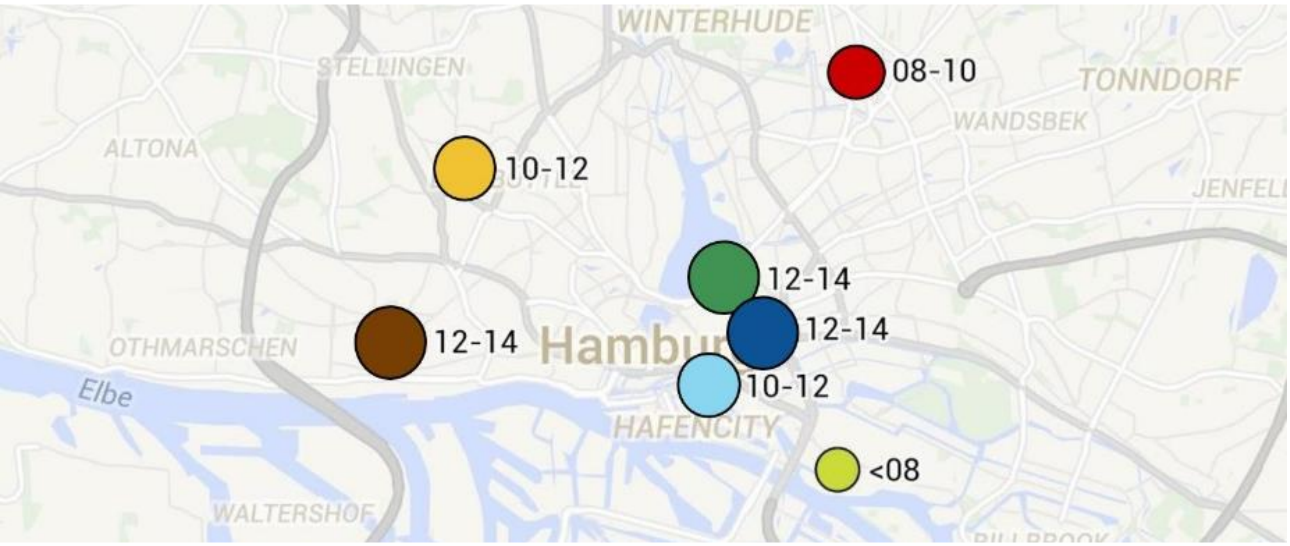


Fig. 4 Rent index in € per m². Source:
http://www.hamburgportal.de/immobilien/Mietwohnungen/mietenspiegel.html

Participation also became an issue when polycentric cities were discussed. The definition of a sub-centre depends a lot on the inhabitants perception, "the ideal did not always correspond to development reality, with many self-declared 'neighbourhoods' either too small to support any land use variety or too large to be considered walkable" [1]. Some of the indicators could hardly be compared because of that. The categorisation of public and private space, for example, turned out to be very different. However, this discussion was essential due to the "legitimate role of the public sector to promote high quality design through planning, site assembly, procurement and investment" [4]. The share of open space ownership was analysed through site surveys in combination with satellite imagery, whereas the public space ratio ranges from 17% to 77% of the total open space area. Related to this interest in open space design, several proposals came up to improve the situation, which show the relevance of it, with regards to other scopes (e-car charging stations for energy, bike lanes for traffic, greenery for water, eg.).

Following the sustainability analysis, the chosen scopes lead to topics for detailed physical interventions:

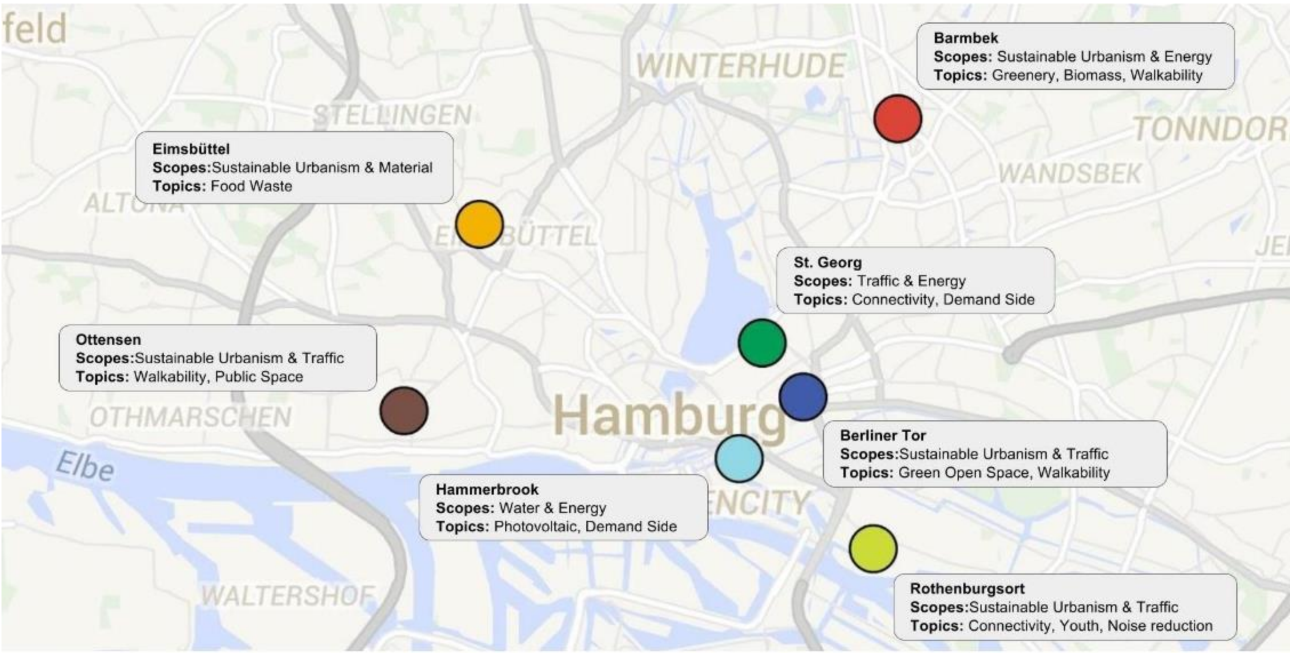


Fig. 5 Focus of groups and chosen scopes. Source: Own Compilation based on HCU REAP P2; Google Maps

Few groups combined two infrastructural sopes, like Traffic and Energy. This was caused by the specific interrelated situation of their quarter. Demand side orientation and connectivity (walkability) were topics which was dealt with in several different proposals. The highlights are subject of the following section.

5. Cases in Hamburg: Topics and remarkable outcome.

5.1 Energetical Analysis of Hammerbrook

Being predominantly industrial and commercial (2% residential land use ratio), the area shows potential for densification (only 758 inhabitants per km²) and better mix of use. Due to the low district coverage ratio, it is suitable for renewable energy production towards a self sufficient quarter (70% of district area is excellent suitable for solar power). The subsequent aim was to propose a demand side managed energy profile for the quarter involving private and public stakeholders.

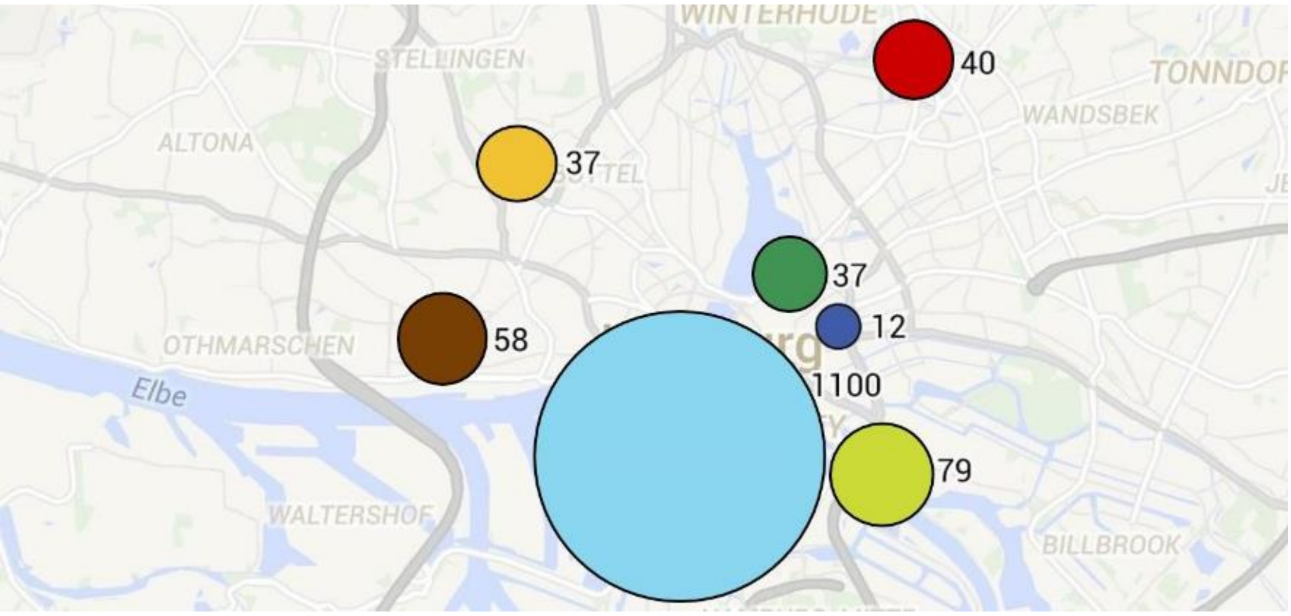


Fig. 6 PV Potential [% of power demand of district inhabitants which could be covered potentially by PV Modules]. Source: Own Compilation based on HCU REAP P2; Google Maps.

The photovoltaic (PV) potential analysis shows better results compared to other locations (Fig. 6), promising the possibility of a self-sufficient quarter in terms of energy. The following design proposal (Fig. 7 & 8) for utilising this potential uses modern PV technology in order to reach almost 20 GWh annually.


Fig. 7 & Fig. 8 Project result: Urban PV Design. Source: REAP P2 (Carstens, Kumar, Abdellatif, Shambulova)

5.2 Food Waste Concept for Eimsbüttel

In order to combine SU with urban material cycles, one team developed a concept for food efficiency. Community based organisations, which collect food waste and process it for low income residents aims to reduce food waste and its related CO2 emissions on the one hand and redistribution of resources on the other. The heart of these activities is a museum to raise awareness about food waste and its consequences.

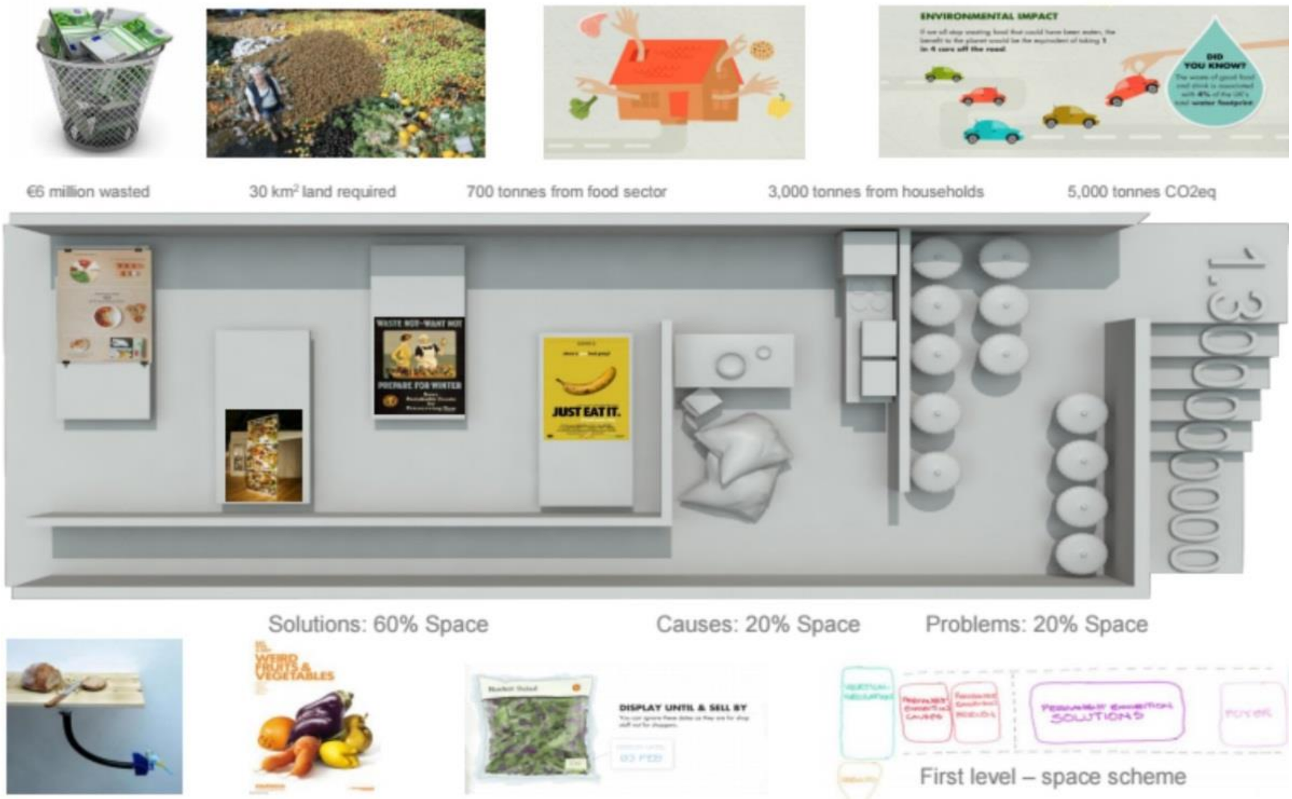
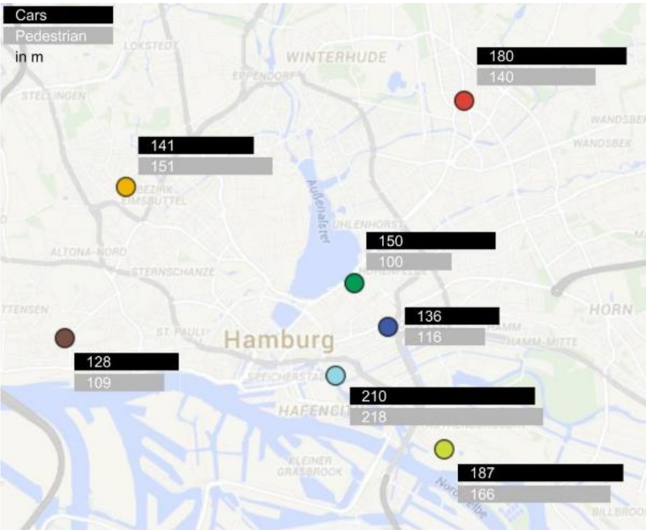


Fig. 9 Project result: Museum for participatory planning Source: REAP P2 (Arazola, Titho, Niessen, Troutman)

The proposal involved participatory planning methodology in order to “involve a dialogue with the customer, whether the existing people within an area or those likely to move in. It is a process that needs to generate and draw upon consumer interest” [4]. Additionally the group developed a concept for the exhibition to form understanding and raise awareness on food waste (Fig. 9). The proposal consists of better use of food waste which is eatable and separated waste management opportunities of biomass coming from food.

5.3 Connectivity as a cross-cutting issue

Polycentric cities are interconnected spaces, within the neighbourhoods, between them and through their regional linkages. Transporting people, providing fair access or influencing the local sense of place, “whatever their function, connections need to be thought of as an integral part of the urban fabric” [4]. Although there is relatively advanced public transportation and safe, fluid roads in Hamburg, many groups identified the need to improve connectivity. Fig. 10 and Fig. 11 give an overview of the two main indicators used to measure and compare connectivity in P2, the average distance between intersections and the cyclomatic number.



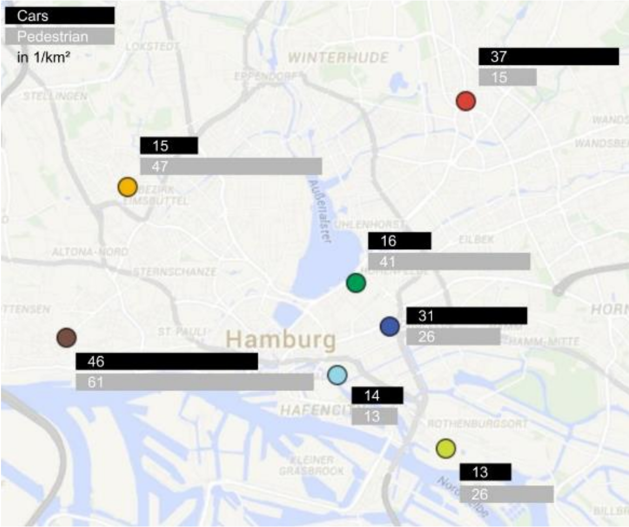


Fig. 10 Distance between Intersections in Hamburg. Source: Own Compilation based on HCU REAP P2; Google Maps.
Fig. 11 Cyclomatic Number in Hamburg. Source: Own Compilation based on HCU REAP P2; Google Maps.

Shortcomings were mainly related to bike lanes and pedestrians, which were being prioritised towards the goal of human scale urbanism and green transportation, while considering the influence of interventions on car traffic. Keeping in mind the socio-economic component, groups aimed to lower income gap by the impact of their physical interventions. An example is the revitalisation of pedestrian networks in Ottensen:

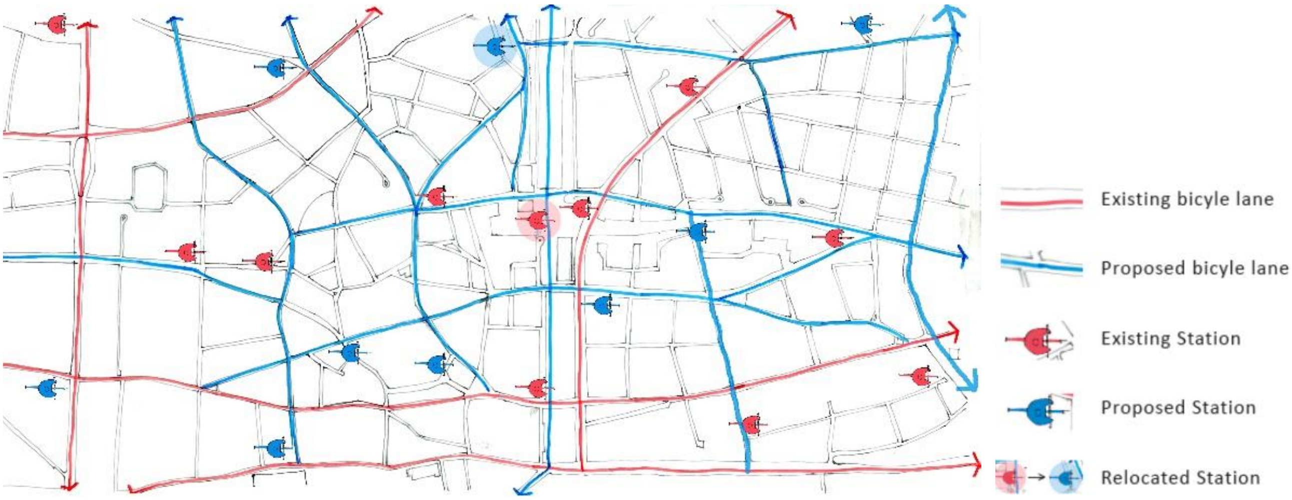


Fig. 12 Project result: Revitalizing bike networks in Ottensen Source: REAP P2 (Callaú, Biber, Netzband, Stancu)

6. Conclusion and Applicability

After a description of SU as base of planning and making clear the conditions of a master's class working on sustainable neighbourhoods, we have shown the major outcome. In order to conclude on these findings, we subsequently highlight practical tendencies on the one side and argue for intensive training of SU principles in order to apply them usefully on the other.

The energy assessment of the first example in Hammerbrook resulted in a demand side management of electrical power and decentralised, local supply through PV. Food Security as a global issue became the focus topic of the second example, which dealt with different solutions to improve efficiency in food consumption and waste management. The third example was lack of connectivity, which was identified in many neighbourhoods. All of the shown examples report of demand side related topics and show that "challenges are now on the consumer side, in the need to recognize the behavioural dimension" [2]. This echoes the need for more participatory planning and tells us the importance of bottom-up strategies as result of the projects by REAP.

Another more abstract conclusion of the projects is the question of how to disseminate and apply ideas of SU. Many interventions show that "the understanding that simply adopting new technology will not be enough; it needs to be fully integrated into the social context in order to deal with the range of complex societal factors" [2]. We acknowledge critics against SU saying that it often works with over-simplified solutions [9], but we see potential in masters programmes like REAP, because it is more broadly discussed than the common best practices culture. Participants not only learn concepts and principles, they are part of an academic process in order to reflect the challenges and opportunities of SU. In contrast to only transfer "discursive truths" [9] Alumni of REAP are able to plan in a highly situational way in their graduate destinations.

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Teaching Sustainability & Strategies of Reuse: Critically Examining Sustainable Design Parameters and Methods of Evaluation

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Summary

In the future, most work for architects and allied professions will involve creatively applying sustainable design principles and impacting existing buildings. These are not new concerns in the practice of architecture, which has always been concerned with multi-parameter optimization concerning the natural and built environments; negotiating present and future needs; and utilizing appropriate technologies and materials. However, the ways schools are teaching sustainability in architectural education is a point of debate. This paper aims to add to the discourse in architectural education for sustainable design. This paper presents findings and discussion relating to the author's experiences teaching sustainable design to architecture students, in two courses designed to take an alternative approach to teaching sustainability. This paper discusses the first phase of a pedagogical study in which findings were focused on the design instructor working directly with students working in groups in intensive courses. The next phases will involve collaborations from neighbouring specialist disciplines, by inviting guest lecturers from climate science and engineering to provide deeper insight on certain topics and facilitating a collaborative workshop with other students from areas of fine arts, environmental engineers, and other areas to mimic realistic design processes with multiple actors.

Keywords: teaching sustainability, architectural education, teaching methods, sustainable renovation, strategies of reuse,

1. Introduction

In the future, most work for architects and allied professions will involve creatively applying sustainable design principles and impacting existing buildings. These are not new concerns in the practice of architecture, which has always been concerned with multi-parameter optimization concerning the natural and built environments; negotiating present and future needs of both clients and society at large; and utilizing appropriate technologies and materials. However, both the profession's approach to sustainable design [1] and the ways schools are teaching sustainability in architectural education are serious points of debate [2]. Sustainable design is now a mainstream topic in architectural education, but it is difficult for instructors to know what to teach. Rather than teaching techniques such as environmental analysis programs like Radiance or industry standards such as LEED, the typical approach is to teach principles, perspectives and develop critical thinking skills the same way architectural education handles other aspects of architectural design. In the same way that architectural students do not learn particularities of building codes or costing, teaching sustainability cannot be about specific tools and techniques as these are in flux and are changing rapidly.

In the practice of architecture, there is no agreed upon definition of a sustainable building. Many architects are becoming frustrated with the idea of sustainable architecture, and it has been called 'an empty box' that means 'what you make of it' [2]. Sustainability itself is not an architectural concept – and it is difficult for many architects to engage with the word in their processes. In fact, in some circles the 's' word is despised, and designers are somehow exhausted by sustainability even though they have not yet mastered it. For example respected architect and theorist Peter Eisenman argued, "Green and sustainability have nothing to do with architecture" [3], practitioner and educator Francois Roche agrees, "I hate the word sustainable" [4]. But sustainability cannot be ignored by educators or by the architectural profession as clients and governmental organizations are demanding sustainable evaluation, either earnestly or 'green washing' and with the noted rise of specialist environmental experts and consultants if architects refuse to engage with these concepts then others will take over certain aspects of projects [5]. Within architectural practice, there are few opportunities to productively debate the words sustainable and architecture together, and there is a disconnect between how the concept is viewed in architectural practice compared to a theoretical research context [6]. Academics are responding but more research needs to be undertaken to demonstrate successful teaching strategies and approaches. The Journal of Architectural Education published an influential special issue on the topic in 2007, "Environmental Architectures and Sustainability: A Taxonomy of Tactics", which offered a provocative and oft-cited collection of approaches in teaching and practicing sustainable architecture [7]. In the UK, a recent editorial summed up some major questions facing architectural educators: should sustainability be integrated into the design curriculum in all aspects?; or be a separate technically focused course?; or be incorporated by integrating landscape more effectively in architectural studies?; or should architectural educators just ignore the 's' word and carry on teaching normal architecture, 'without prefixes'? [8].

So how is the most engaging way to teach these concepts despite the fact that the concept of sustainable design is complex, in flux, and disputed? Each site, client and design concept is unique, so one 'solution' or even one set of parameters can never be prescribed. In many schools of architecture, sustainable design is taught in parallel to design as a building science topic, where students are instructed in broad concepts like energy efficiency and thermal comfort by specialists, like engineers and technologists, rather than their design studio instructors. However, the future of the profession is dependent on how well we educate and inspire students in a range of creative, sustainable approaches, including complementary thinking [9] where qualitative and quantitative parameters are balanced to give a holistic perspective to the phenomenon and the focus is on a range of scales from macro to mirco. Architecturally, the concept of "relative sustainability" is meaningful [10] because thinking of sustainability as being a range of relative measures, rather than an absolute determination of sustainable or not, is a practical way of considering such a multi-faceted and complex term. In a connected issue, in architectural education renovation should be explored as a creative design process with inherent sustainable qualities. Despite the fact that renovation is a highly practical design problem in practice, students in schools of architecture are typically encouraged to design new buildings to explore design ideas. When it is a design focus, renovation is often considered an atypical assignment, imposing undesirable design constraints, and offering the student less ability to be creative than 'empty' sites with no restrictions. This paper argues that sustainable renovation can be highly creative and allow for innovative designs and that new teaching methods should be experimented with to engage students in sustainable design and encourage critical thinking, and to design strategies of reuse and renovation at multiple scales. This paper offers no answer to how best to teach sustainable design but does present findings and discussion relating to the author's experiences teaching sustainable design to architecture students in two courses designed to take an alternative approach to teaching sustainability.

2. Methodology

This paper presents findings from the author´s experiences of teaching sustainability and sustainable renovation to undergraduate architecture students. This paper discusses the first phase of a pedagogical study focused on a course design where the design instructor worked directly with students. The architecture students worked primarily in small groups of two or three of their peers. The next phases will involve collaborations from neighbouring specialist disciplines, by inviting guest lecturers from climate science and engineering to provide deeper insight on certain topics and facilitating a collaborative workshop component where students work in small groups that include students from other areas of expertise. It is planned that these neighbouring specialist disciplines could include fine arts, landscape design, environmental engineering, and other areas in order to mimic a realistic design process with multiple actors.

Several methods for teaching sustainable design served as inspiration for the courses. The author's own experience in architectural school relating to vernacular building and sustainable design was in an educational design build setting [11], an established part of architectural education where students make a 1:1 structure. The experience of planning, drawing and building a structure and learning about the local site, orientation, footprint, and investigation of vernacular building techniques were key to the author's understanding of sustainable design. Another well known teaching method is the design charette, a quick design study where students develop specific designs in an intense design period. This method has been tested focused specifically on certain sustainable design concepts and typically involves collaborative working methods [12]. The workshop component in 'Sustainability: Strategies of Reuse' discussed here had some characteristics of a charette.

The aim of the pedagogical study presented in the two educational experiments described in this paper was to encourage the students to critically reflect about what it means to be sustainable and to foster concepts of environmental stewardship. This teaching took place during the author's PhD research in the faculty of architecture in sustainable renovation. The first example presented in this paper, the results of the one week long theory elective 'Designing Sustainability' was designed to encourage students to develop a critical framework for considering the definition and evaluation methods of sustainable design. In developing this sustainable design theory course for a small class of undergraduates, the aim was to structure a course that could help students identify sustainable design concepts that they found personally relevant to their project, and to understand some aspects of the histories of these strategies. The course was designed so that the students would agree on a working definition of key terms, determine priorities for their design, incorporating concepts of relative sustainability, and create a drawing of their project as it might appear in the future to creatively engage with concepts of lifecycle. The aim of the course was to enable students to conceptualize sustainable architecture as an architectural concern, and to be able to debate, convince, discuss and engage with sustainable design issues with their peers.

The second example presented in this paper is the results of the 'Sustainability: Strategies of Reuse' workshop which took place in the first two weeks of the Design studio course. This workshop was taught by the design studio instructors, the author and experienced instructor Prof. Inge Vestergaard, and was embedded in the design studio which focused on sustainable renovation.

The aim of the workshop was to introduce critical engagement with strategies of reuse at multiple scales, starting with material, furniture and interior before moving up in scale to a building in the final design project later in the semester. This workshop served as an introductory exercise for the studio, encouraging the students to get to know each other, work in groups and find local resources. The workshop proposed thinking about reusing material in creative ways, sourcing and identifying appropriate materials and considering particular issues of scale, and lifecycle.

3. Results

3.1 Designing Sustainability Seminar

'Designing Sustainability' was offered to second year architecture students as an undergraduate elective in Spring 2010. Taught and developed by the author, it aimed to reinforce and support the design studio and building technology courses for the students, offering a critical theory perspective. The intention of the course was to explore how enlarging the scope of the concept "sustainability" can allow it to inform the architectural design process. The course aimed primarily to teach students to critically examine the term "sustainable" design and the way it is evaluated. It was hoped that students would see the concept´s potentials rather than limitations, as sustainable design is firmly a part of the culture of architecture school.

In the first meeting of the course, the class developed a long list of how sustainability should or could be considered in relation to a single-family home. This building type was chosen because it was their design studio project for the year, which they were designing in parallel to this seminar course. Again using the example of their own home, students were asked first to rate their home on a scale of one to ten through a show of hands to indicate how sustainable their home is. This exercise led the students to conclude that it depends on which criteria are used for the evaluation. Then students listed what parameters makes their home sustainable (or not) and all of the parameters were written without editing on a whiteboard in the studio. More than forty extremely diverse "sustainable" criteria were listed and later debated well into the evening. In no particular order, the students found these were the best criteria for judging sustainability of their own home were: strong materials to last a long time; cost to maintain; architectural quality; ease of maintenance; energy use; proximity to amenities; land size and amount of garden; number of people living there (density); age value; possibility for food production; views to outside; fresh air; heritage value; suitability for the climate; pleasing colour; influence on resident behaviour (the stairs being good for exercise); if it makes residents happy or not; if it is drafty or airtight. The students concluded that depending on the specific social and economic context, location, site characteristics, building type, building age, and brief, almost any quality could be a sustainable parameter.

3.1.1 Site Specific Sustainability

After a series of lectures and readings, the students began on their assignment of selecting and analysing a sustainable house for a precedent study. The students worked individually to select a house, identify which sustainable priorities it seemed to have, and communicating the findings to the class. Each chose a house, identified four sustainable parameters (from the long list they developed together) and then made a graphic to show where the house design rated on the spectrum of sustainability given their chosen criteria. One student chose the Schroder House in Utrecht designed in 1924 by Gerrit Thomas Rietveld. The student presented architectural drawings, interior and exterior photographs and argued in a presentation that its high quality and flexible interior design made it a good precedent study. The assignment called for him to evaluate the

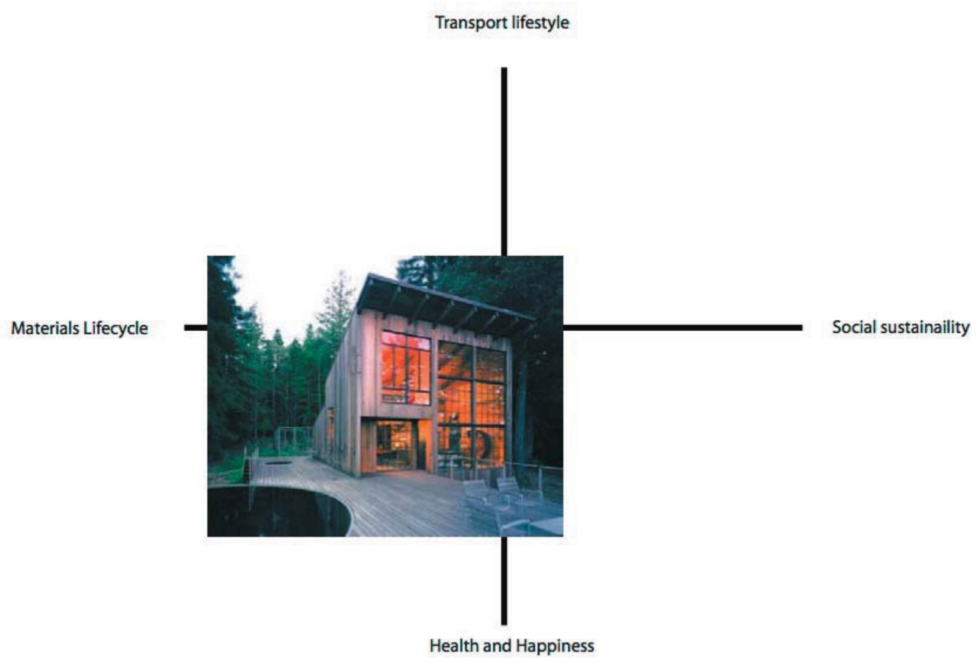

Fig. 1 Students in the ‘Designing Sustainability’ course chose housing precedents and graphically noted where they determined it fit with the chosen sustainability priorities. This example is the Bruer Lundberg Cabin by Lundberg Architects in California.

sustainability of the project and he chose four parameters that he thought would be important in this particular house: social sustainability, materials, flexibility and adaptability, and acoustic comfort. He prepared a short text about how these were addressed then made a diagram of how he thought the building performed against these criteria, graphically showing it low on social sustainability, and higher on flexibility and adaptability. Another student chose the Breuer Lundberg Cabin by Lundberg Architects a home built as a nearly self-sufficient house in California and assessed it against her chosen sustainability priorities. Both examples sparked an interesting debate about what the subjective term “social sustainability” might mean. In this sustainability evaluation exercise the students learned first hand that language and metrics matter: the categories used for the evaluation are what make a building sustainable or not, and determines where it could be placed on the spectrum of sustainable design. If a house is designed with energy savings in mind then it could be sustainable in different ways to for example a house designed with natural materials or food growing potentials in mind. In small groups they presented their precedent studies to each other and debated the categories selected.

3.1.2 Drawing Sustainability

The final exercise involved each student producing or adapting an existing drawing, in any medium and at any scale. This drawing related to their current studio project, a single-family house design. The seminar was designed to encourage the students to develop their own understanding of a concept and discover how sustainable concepts and approaches could be a driver during their own design process.

Fig. 2 In the ‘Designing Sustainability’ course, student David Steen Hansen tried to communicate adaptability and future transformation.

Fig. 3 In the ‘Designing Sustainability’ course, student Martin Erlandsson made a very large mix media drawing and painting of the concept of transformation with old.

The students found that was difficult to draw certain aspects of sustainability. The students struggled with how they might draw or represent adaptability or something being able to change over time. They wanted to draw how their building will house future generations or how it could be added to over time. In the group discussions for each project, the students agreed that it was extremely difficult to architecturally communicate time, quality, acoustic performance or energy savings using typical methods of representation. They asked: “but how can we design for something we cannot draw?”

3.2 ‘Sustainability: Strategies of Reuse’ Design Studio Teaching

The second educational experiment discussed in this paper is the ‘Sustainability: Strategies of Reuse’ workshop. This undergraduate architectural design studio was co-taught by the author in September 2010. The format was an intensive two-week workshop where the students were asked to work in small groups and design and build a 1:1 construction using found materials relating to the scale of the body. This workshop was inspired by the author´s study and analysis of the Harvest Maps created by architects 2012architekten who practice what they call “resource based design” [13]. Harvest Maps are drawings that the office creates for each of their projects to understand and identify various local resources in the area that could be of use to the project [14]. The ‘Sustainability: Strategies of Reuse’ workshop tried to translate this concept into a short design exercise in an undergraduate studio environment. The workshop had three components: a visit to local waste recycling facilities, a sourcebook created by the students of precedents of building using waste materials and a 1:1 material experiment. The third component, the 1:1 constructions, are focused on for this paper.

The intentions of the workshop were to introduce a main design studio theme of sustainable renovation by starting with a short design exercise investigating strategies of reuse at various scales. The students joined this particular studio because they were interested in designing a renovation to an existing building and they wanted to know how their design could be more environmentally sustainable. Following this workshop, the students had lectures and readings about embodied energy and waste in construction leading into the beginning of the design studio where there was a site and brief for a renovation.

Fig. 4 ‘In the ‘Strategies of Reuse’ Workshop, students worked in groups to reuse and transform found materials. Groups reused plastic bags to make a canopy; rolled newspapers into a chair; pleated newspapers to make a dress; stacked and attached shoeboxes to form a shelter; and reused tires to make a hammock.

The assignment was to find and transform a freely available material to create something beautiful that the group could learn from as an example of waste material being reused. The students were responsible for where the materials could come from, how to transport them, and what might happen to it once they were finished with it. The studio was divided into eight groups and they had a short time to find materials and decide on a strategy. This workshop was a modified charette format. The projects were assembled in the shared studio space and there were many group discussions throughout the workshop and chances for students to change direction, consider how the materials could be joined, and test performance. The students were able to observe other groups, share techniques for joining materials and learn collaborative work practices.

4. Discussion

While sustainability in architecture is often defined according to the so-called Brundtland definition, specifically with regard to meeting present needs while not compromising the ability of future generations to meet their own needs [15], this is not necessarily relevant to architecture students. Often criticized for its generality, it offers nothing specific of how sustainability looks, functions, influences, is experienced, or delights. Architects are well placed as a profession to grasp the overall complexity inherent in sustainable design and sustainable transformation, but how can we encourage this advocacy in design students?

It is important that architecture students learn that sustainable design is more than just energy calculations or building performance. The intention of the work shown here was to make the topic of sustainability into a creative theme with many different ways to approach it. The aim was to provoke, inspire, inform, and to foster critical thinking skills in the students. The short course length and the small group for ‘Designing Sustainability’ helped make the format a success. For example, in the first exercise where the students defined various criteria for sustainability, each student actively participated. The students found that if nearly all design criteria can be interpreted as a sustainable criteria, then the important thing was to select priorities for their design and then design, respond and evaluate accordingly. They found it was meaningless to try to design for general “sustainability” qualities but rather they needed to develop a local, specific and tuned approach. Rather than a one week course in a digital tool for daylight analysis like Radiance or the LEED building standard, which will likely change radically in the next few years, the main ideas of the teaching were to work towards integrating sustainable design into the architectural design process.

In the ‘Designing Sustainability’ drawing exercise, students lacked the abilities to describe and creatively represent many of the desired sustainable design concepts. The students were not satisfied with drawing arrows to show sound as a bouncing ray or to show their house several times in series with different uses showing its change over time. They actually began to change their sustainability concepts to suit what they could draw. One student initially wanted to show his building over time in a series of drawings or layers over a main drawing, but given the short course format, ended up showing daylight because it was easier to show light and shadow using conventions that he knew. In a longer course there could have been valuable time for experimentation of different representation techniques and multi-media. Initially, students were wary of producing a drawing to pin on the wall that they could only complete in one day, as it was introduced in the morning, handed in that evening and presented the following day. The short time frame seemed to make students able to take more risks, as they were not committing much time to the drawing, and could experiment with different approaches and media, like chalk, charcoal, layers of drawings, and larger formats.

In the ‘Sustainability: Strategies of Reuse’ workshop, a main finding of the 1:1 constructions was that the students had difficulty drawing material details and they found assembling and testing materials and structures at 1:1 much easier. After they made a series of full-scale assemblies and joint details, they were then more confident in drawing these aspects. The students became more engaged with their local environment, with a new knowledge of local waste and recycling depots, and local industries such as shipping and shipbuilding. After the workshop they appeared more engaged with resource based design concepts as opposed to when they had only read about them the week earlier. A constraint in the evaluation of the 1:1 constructions was that students were told to focus on creating beautiful constructions, so just because the materials were freely available it did not excuse sloppy execution or lack of conceptual idea. The feedback by the group and instructors to students was primarily about architectural concept and material details, not about why they chose the particular material. The short hand-on workshop gave the students a deeper understanding of reuse of material and especially an appreciation for how the method of connecting materials is important if they are to be reused again. One way that this workshop could have been improved is that the students could have formed multi-disciplinary groups including students from perhaps the design conservation or engineering schools. A multi-disciplinary group would perhaps be more challenging, but would likely yield stronger results that could be taken into the design studio projects. Following the workshop the students participated in a school-wide exhibition and had the chance to see the final works of each of their groups along side all of the other design studios who also had short workshops on various themes such as sound, landscape and parametric design as primers to their design studios.

5. Conclusions

There remains an ongoing debate about how to teach sustainable design in architectural education. With varying cultural and social contexts, ages and abilities of students and specific environmental and political concerns there can be no one answer as to the best way to approach teaching such a complex topic. However, it is intended that this paper add to a growing pool of academic papers that attempt to experiment with, document and disseminate the results of sustainable design courses, analysing the successes and opportunities for improvement. This paper reveals the thinking underlying the design of two courses and analyses the instructor’s impressions of the success of the course using these teaching methods, course structures and and approaches. in this area can lead to new knowledge which can in turn lead to better teaching. The author’s view that the multi-faceted challenges of sustainable design need to be well integrated into the overall education and practice of architecture was reinforced in teaching these courses. There is value in teaching sustainable design as a creative, design topic, and as well sustainable renovation and strategies of resuse can be conceptual and non-technical. The course format and size of the student groups in these courses helped make the courses successful. Both courses utilized small group learning settings with plenty of time scheduled for discussion. The assignments were quick creative design exercises that the students presented to the wider group and to the instructors for immediate feedback. The students were able to gain practice explaining their work to their peers and to the instructor. The 1:1 material studies were even more useful than expected and helped the students with their drawing and conceptualizing of problems. Encouraging a range of sustainable design definitions and approaches, as well as supporting local concerns, personal narratives, and untested ideas have proven very useful in engaging students and generating debate. This pedagogical study focused on the design instructor working directly with students working in groups in intensive courses. The next phases will involve collaborations from neighbouring specialist disciplines, by inviting guest lecturers from climate science and engineering to provide deeper insight on certain topics and facilitating a collaborative workshop with other students from areas of fine arts, environmental engineers, and other areas to mimic realistic design processes with multiple actors. The question of how to encourage stewardship of the built and natural environments in students is important one, and remains a pressing concern for educators who seek to instil these values in students.

6. Acknowledgements

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The aspect of space in future energy systems

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Summary

The concept of hybrid grids is focusing on regional and supraregional levels. Energetic Neighborhood (EN) adapts the abstract concept and offers a set of technical and conceptual approaches to face the local situation on district level.
From the perspective of stakeholders and facilities within a district (companies, houses, plants etc.), the approach of EN means, that those who are in close proximity to each other, exchange energy and energy surpluses with each other so less primary energy is consumed in total.
Using a space-analytical approach, a method will be developed that different, previously separated energy domains integrates considering the specific “effective radius” of technical solutions and energy domains. The paper shows framework conditions, first analytical model concepts and interfaces to municipal energy planning issues.

Keywords: Energetic Neighborhood, hybrid grid, local implementation, energy planning

1. Introduction

One of the core challenges of the Energy Transition in Germany is the growing storage gap within the power system. The term storage gap describes the lack of flexibility in the power grid, in order to store surplus energy during light load periods and to offer this stored energy during peak load periods. Additionally, the heat/cold - sector comes into focus, because there is a high potential for energy saving and climate protection [1]. The transition from fossil fuel g towards renewable energy for heating and processes is one of the most important issues in the next years, to achieve the climate protection goals [2].
Smart energy management approaches are used to flexibilize and couple demand and supply processes, the so called Smart Grid [3]. Much discussed is the load shift of consumption processes. Hereby, long term and seasonally applicable shift capacity cannot be developed. When there is a high productivity e.g. of solar power in summer (Fig. 1), the price decreases and it could be feasible to use the power to generate heat or cold.

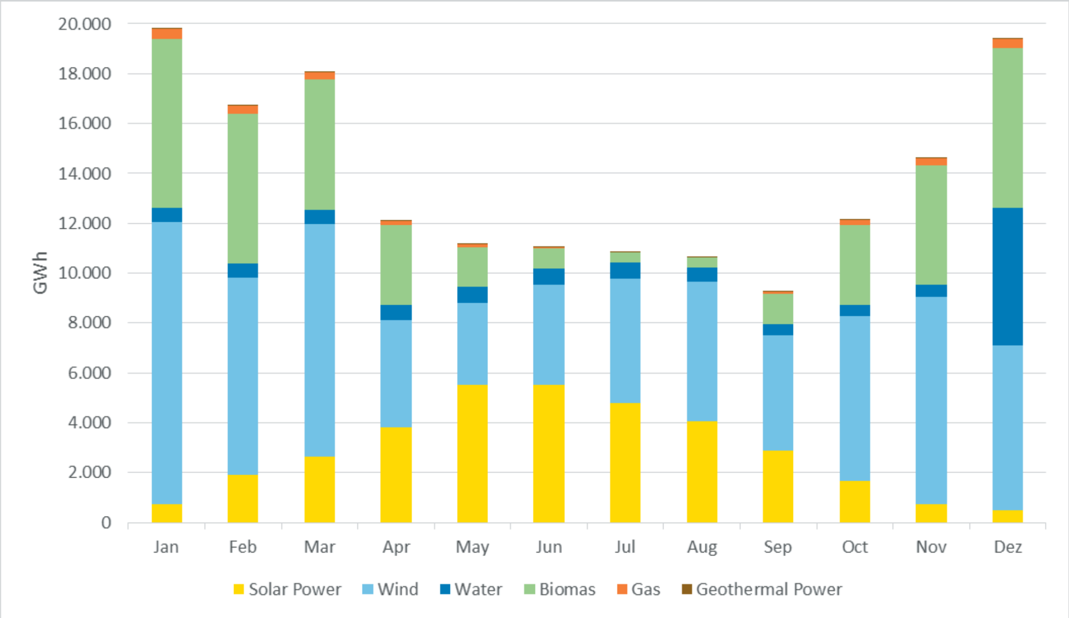

Fig. 1 Estimated power generation, based on plant register of 08/2015 [29]

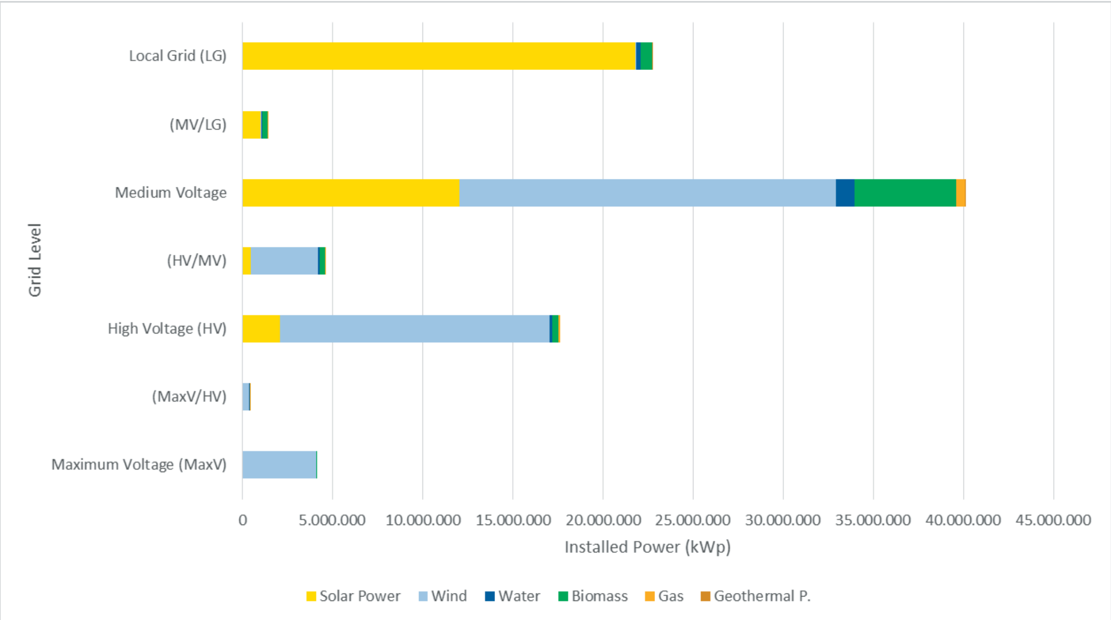

Fig. 2 Installed Power (kWp) on grid level, based on plant register of 08/2015 [29]

Besides the supraregional power generation in offshore and onshore wind farms and the related high-voltage grids on the one hand and the gas distribution grid on the other hand, a huge amount of decentralized power plants are installed in Germany on the local and medium grid level (Fig. 2). So the integration of decentralized plants is first of all a local and regional issue.

The problem will be exacerbated by the further supply and expansion of renewable energy generation facilities [4] and other high efficient plants like CHP-plants [5]. One solution could be to bring more storage capacity into the grid. Another way is to enable more flexibility by coupling different energy domains on local level. Most of the CHP-plants in Germany are feeding in the local and medium power grid level, so it is necessary to balance between the heat demand on the one hand and the situation in the power grid with stochastic power plants and controllable power plants on the other hand (see also [6]).
Both, power storage and coupling of different energy domains, will be the key factors for a successful Energy Transition. Power-to-Gas, for example, is able to stabilize the local power grid by capturing peak loads and transforming the energy into gas [7] [8]. Mobile energy systems like e-mobility and moveable heat storage systems are treated in this contribution like stationary systems. Although, their behavior and the potential of demand site management is from a spatial point of view highly flexible, but from a stochastic point of view it is nearly stationary.

The challenge is to make the theoretical concepts more explicit on local level. The dynamic of demand and generation of energy and the necessity of placing plants leads to a relationship of tension, because it is foreseeable, that a spatial configuration of e.g. a district heating system with one generation plant is in some phases and in some areas of a settlement not economical [9].
The current contribution analyses existing approaches and concepts and presents an explicit spatial approach with the focus on future energy systems. It represents the incipient project at the Jade University of Applied Sciences in Oldenburg.

2. Existing Approaches and Concepts

2.1 Spatial Approaches in Energy Concepts

The consideration of the spatial aspect in energy concepts mostly follows analysis of energy potentials and constraints within an energy domain [10]. Another way is to optimize the site of a storage facility in a district heating system [11]. Other analysis focus on energy demand and the optimized energy mix on regional level [12].
The model KomMod [13] is able to take into account and to visualize the energy flow within a city for different energy domains. Municipalities can use this model to address energy coupling and expansion options, supporting the local energy strategy. But the spatial disaggregation is announced as an issue to be solved [13, p. 586]
Municipal motivated energy usage and development plans, e.g. Nürnberg, Augsburg etc., are structured sectoral. An energy optimization takes place at the level of districts and is thus tailored to a predetermined administrative shape. Options for connecting the energy domains are not shown. An integral approach represent the currently discussed Energy Master Plan (“Energieleitplan”) [14]. The project UrbanReNet also shows an integral approach to combine different energy domains, but the starting point of the modelling is a predefined morphological characterization of “energetic settlement area types” [15].

2.2 The Concept of Neighborhood

The Energy Transition is not only an issue on national level, although the high voltage supragrid is discussed very intensively [16]. The establishment of the future energy system will happen on local level, within the districts of a town and in the relationship between town and rural areas. So it is necessary to define the spatial aspect from a broader energy point of view, to make it operable and communicable.

The term “district” is an area characterized by a particular feature or activity or it is a term to describe administrative borders [17]. But this definition is too rigid, because energy infrastructures, potentials and effective radii of energy processes don’t stop at administrative borders.
The term neighborhood is more helpful, because it contains more than physical and administrative parameters. Neighborhood contains and represents [17]:

- a district or community within a town or city (spatial approach)
- the area surrounding a particular place, person or object (relational approach)
- neighborly feeling or conduct (feeling)

Galster [18] describes neighborhood with at least 10 characteristics:

1. Structural characteristics of the residential and non-residential building
2. Infrastructural characteristics
3. Demographic characteristics of the resident population
4. Class status characteristics of the resident population
5. Tax/public service package characteristics
6. Environmental characteristics
7. Proximity characteristics
8. Political characteristics
9. Social-interactive characteristics
10. Sentimental characteristics

This characteristics seemed to be very sociological, but they are, besides the technical issues, indeed important impact factors for modelling the spread of renewable energy plants, too [19].

From the energy point of view, there are no clearly defined districts, especially in the context of flexible coupling in the sense of a hybrid grid. Existing grids like gas grid, power grid and district heating systems are not relevant in this state of the concept, because the concept wants to show, how the future energy system could be. Later, the existing grid(s) will used as a starting point in concrete areas.

So the spatial fuzziness of neighborhoods is an opportunity to identify “solution areas” in a spatial point of view, to achieve a suitable configuration of facilities and plants.

2.3 Future Energy Systems and Energetic Neighborhood

The future energy system will combine different energy domains [20] and use cases with various physical and virtual coupling points between power and heat / cold [21].

Hybrid grids are not only systems with polygeneration facilities of energy, but also with different coupling facilities to enable switching between the energy domains. Physical and, as far as possible, virtual coupling points have to be found and to be located in concrete sites [22].

The currently developed approach, Energetic Neighborhood (EN), aims to realize the concept of hybrid grids [6] on a local level and is described in various papers (see [22] [23]):
“The approach aims to minimize the energetic process distances (number of lossy energy conversion processes) caused by the transformations as far as possible. Here, a variety of approaches can be combined:

- Direct coupling within an energy domain
- Reduction of the transformation processes
- Reduction of losses by spatial proximity
- Consideration of the respective energy levels” [22, p. 1]

“An EN is thus a composite of actors, which are to each other in spatial proximity and convert the energy needed to carry out their usual processes as a side effect into other energy forms, which are required by another player from the composite as input for its own processes” [22, p. 1] based on [23]. “Energy efficiency measures are thus treated at the area level and are no longer left solely to the individual players.” [22, p. 1]

EN takes up the spatial fuzziness of neighborhood and stressed out the importance of relations between several actors. Additionally, the set of energy actors (demand/supply) determinates the shapes and extends of specific EN, which are subject of temporal and spatial fluctuation.

The challenge is to define core areas of specific generation and distribution technologies (e.g. district heating systems), areas of individual energy generation and the areas to couple those areas, if a useable surplus energy is available. In the respective areas there will also be decentralized couplings, but on lower level. In specific investigation areas the existing grid (gas, power, sewage etc.) should be taken into account as a base for scenarios.

The coupling technologies to use surplus energy are manifold:
Power-to-Heat (e.g. heatpumps), Power-to-Gas (e.g. electrolyzers), Heat-to-Power (e.g. ORC) etc. In the current state of technology Power-to-Heat and Power-to-Mobility have the greatest effect for climate protection [24].

2.4 The Concept of the Effective Radius

Each energy facility has a specific, so called effective radius [25]. The effective radius takes into account transport losses and costs, the quantity and quality of the energy, and the temporal availability. With the help of effective radius it is possible to detect coupling potentials between e.g. district heating systems and companies with a surplus of process energy, which is useable by heat exchangers. The same information is also useable to detect suitable consumer of the surplus energy within the neighborhood.
The Bavarian Energy Portal (http://geoportal.bayern.de/energieatlas-karten) offers on cartographical overview of the effective radii, so the potential energy user can get information about the quantity and quality of the energy within the radius [26].

2.5 The Concept of the Heatmaps

The intention of heat maps is to stress out the density of a certain phenomenon. In energy context often the heat demand is analyzed and visualized by heat maps. The result shows a raster-based overview. The parameters for the calculation are often take from literature (e.g. 20x20m, 160m search radius) [27], but there is no linking to the parameters of the facilities.

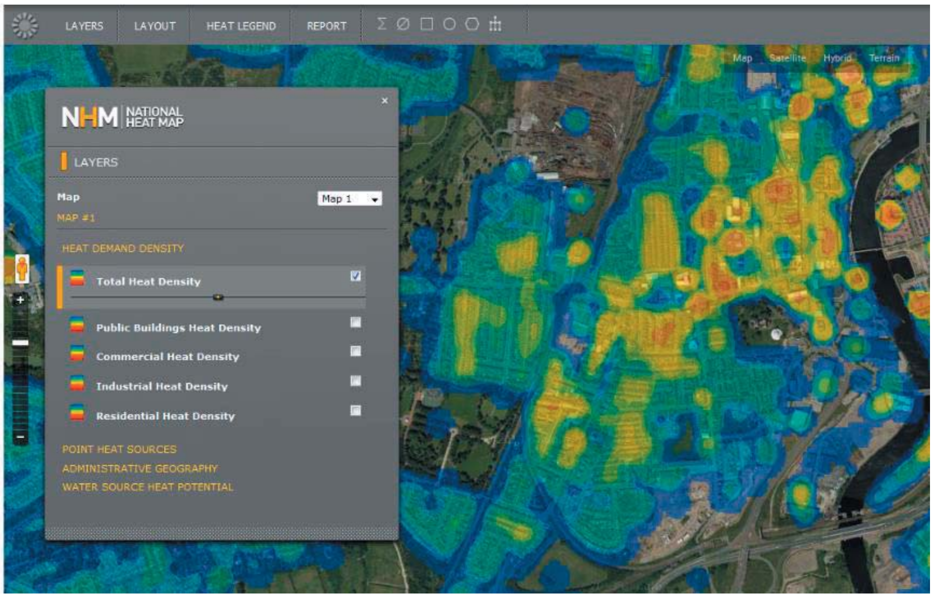

Fig. 3 Example of Heatmap (here: Energy Demand) in England [30]

A heatmap allows to identify where e.g. district heating systems could be build and where not [9]. The most important fact is, that heatmaps do not offer a clear base for decisions. The gradual information has to be evaluated by other parameters like costs, accessibility etc.
Another intention pursues the heatmap of Aberdeen [28]: The map and the study detect potential energy relations of actors and the potential energy cooperation between sites.

3. Integrated Approach

The application field of this approach is focused on the gap between urban planning and detailed planning and is shown in the following figure:

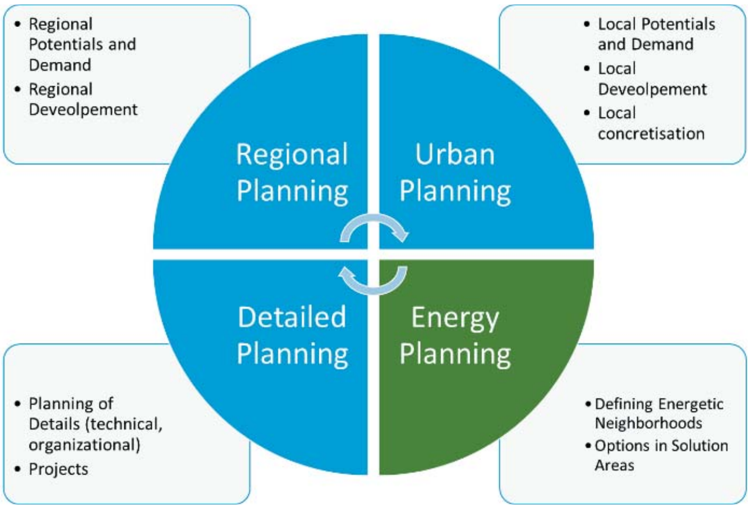

Fig. 4 Application Field of the integrated Planning Approach

The approach will be illustrated by a fictional example based on OpenStreetMap-data. The figures and facts for heat demand, effective radii etc. are fictional, too. The maps demonstrate the principle of the approach and not a real world example. Energy demand and supply, especially the supply of renewable and surplus energy is not statical, so the shapes are pulsing in space and time with more or less sharp borders and even overlapping areas (see Fig 4), the so called fuzziness of energetic neighborhoods.

Fig. 5 Example of an integration of heat demand, potential and different temporal states of effective radii

The following figure illustrates the fluctuation of effective radii (e.g. surplus heat energy of production processes) mapped on an overview of heat demand.

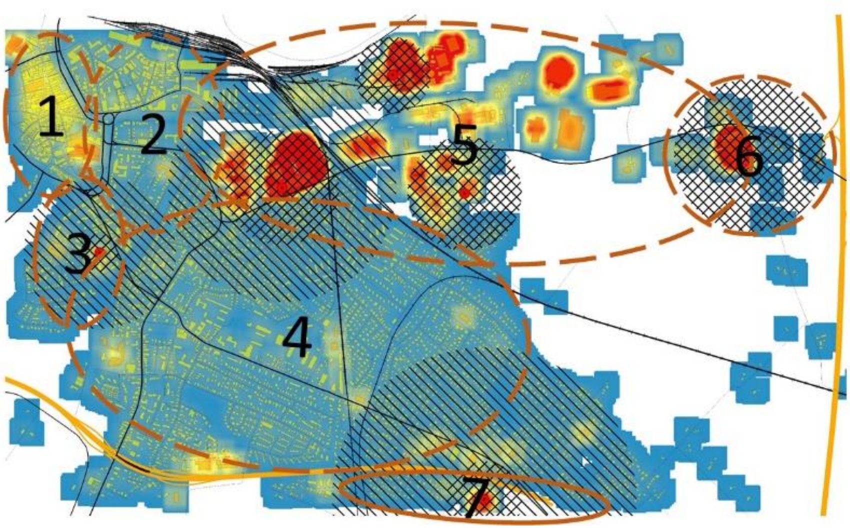

Fig. 6 Example of an integration of heat map (density) solution areas

A method is to develop to define and describe the areas with an optimized set of energy supply systems under the perspective of climate protection and cost efficiency. For each “solution area” it is possible to find out the appropriate technologies with the help of geostatistical methods. The overlapping areas are very important to discuss hybrid energy coupling systems on district level connecting the neighborhoods. In figure 5 the solution area No. 4 is connected to No. 3, 5 and 7 temporally. So a district heating system could take into account the surplus energy from the other areas considering the energy quality and quantity.

For example, the surplus energy of a company of 60 degrees Celsius are usable as a feed into a district heating system, but are not usable for further processes within the company.

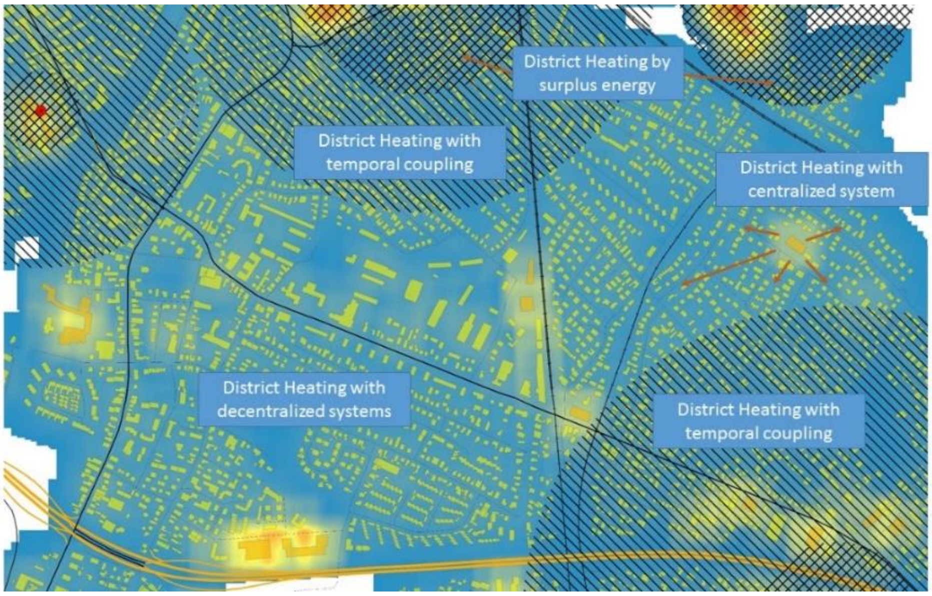

Fig. 7 Close up on potential solution areas

The close up illustrates the fuzziness of the solution areas. More exact boundaries are to be determined from an energy point of view.

4. Outlook

The project “The spatial reference in future energy systems” just started at the Jade University of Applied Sciences in Oldenburg (Lower Saxony, Germany). In the next three years it is foreseen to develop a method to define and describe solution areas of Energetic Neighborhoods with an optimized set of energy supply systems under the perspective of climate protection and cost efficiency. The fluctuation of Energetic Neighborhoods in space and time will be formalized and tested in concrete urban areas. Different approaches will be tested:

- Spatial modelling:
  Modelling the spatial fuzziness and suitability of solution areas for EN
- Visualisation of spatio-temporal energy flows
  The visualisation of complex energy issues supports the decision making
- Modelling the facility setting:
  Modelling different sets of facilities and coupling points of energy domains within the solution areas. Agent based modelling and prediction by neuronal networks will be analyzed

The project is carried out with close relation to planning authorities on municipal level, and with the intention to develop a transferable planning guideline.

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The effect of water dosage on the properties of wet spray cellulose insulation

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Summary

The thermal and mechanical properties of cellulose fibre insulation, installed via the wet spray projection method, were studied. The isotherms of loose fibres were determined using dynamic vapour sorption to study their behaviour with water. Wet spray cellulose samples with varying water content were subjected to compression, and thermal conductivity testing. Results showed density, modulus of elasticity, and thermal conductivity all increased with water dosage. These factors are to be considered for when applying wet-spray cellulose fibre insulation to ensure the properties of the material are consistent.

Keywords: Cellulose insulation, thermal conductivity, recycled paper, compression, moisture sorption,

1. Introduction:

In the building sector, there is an increasing interest in construction materials that incorporate natural fibres. Not only do these materials have a reduced environmental impact than more traditional materials, they also have good thermal acoustic, and moisture absorbing properties. One such material is cellulose, an insulation material that is made of ground newspaper fibres treated with fire retardant chemicals. Since it uses recycled materials and requires little energy to produce, it has less embodied energy than traditional materials such as mineral wool, and even materials based on cellulosic fibres such as wood fibre insulation [1].

There are two main methods of applying cellulose fibre insulation: “loose fill” where the fibres are blown into attics or closed wall cavities using specialized equipment, and “wet spray” where water is atomized and sprayed while the fibres are blown into open wall cavities. The water makes the fibres adhere to the cavity, in order to prevent sagging and ensure a homogeneous distribution of the fibres. After spraying, the excess material is removed via an electric wall scrubber to ensure a flat surface. The wet-spray method also provides a better air tightness for a buildings envelope, preventing the loss of heat caused by air infiltration through voids [2].

An issue with the wet-spray method of applying cellulose insulation is the control of water during spraying. If too little water is applied to the cellulose, the fibres might sag or unstick to the wall. Conversely if too much water is applied, the fibres will have a better cohesion to the wall cavity and to themselves, but the material will require more time to dry before a vapour barrier and/or drywall, depending on ambient conditions. In the work of Salonvaara et al [3], the modelled drying of wet spray cellulose varied greatly depending on the month and location it was installed, with cellulose installed in winter months taking several weeks to reach a dry state. Incidentally, in the same study, wet spray cellulose that was intended to be installed at the minimum recommended water dosage of 40%, turned out to be installed at a dosage of 70%. This shows, albeit anecdotally, that professional installers might have difficulty controlling the initial water content of wet spray cellulose insulation.

Most research on cellulose insulation focuses on the loose-fill application. The influence of adsorbed humidity on thermal conductivity on loose fill cellulose fibres has been studied. A linear relation between moisture content and thermal conductivity has been established [4, 5, 6]. These studies consider only the influence of humidity contained within the loose fibres, and not how drying of fibres can influence these properties. It has been shown that once paper fibres dry, their strength increases, porosity decreases, and their moisture retention capacity decreases [7]. These changes in the fibre structure during drying can also affect the thermal conductivity of cellulose insulation, which has yet to be studied.

For loose fill applications, methods have been developed to test the settling of loose fibres in attics [8, 9]. A model to study mechanical behaviour of loose fill fibres in a closed cavity is detailed in the work done by Rasmussen [10, 11]. This model studies the creep behaviour of loose fibres in a closed wall cavity in order to predict the necessary installed density to prevent settling. The model used friction coefficients with the surface the cellulose fibres are installed on oriented strand board (OSB) closed wall cavities. In the case of cellulose insulation installed through the wet spray method, the fibres are rigid once they dry and adhere directly to the wall cavity. The measurements used on loose fill therefore do not apply to the wet spray application and there has yet to be a defined method to quantify the mechanical performance of materials fabricated with this method. The contribution of water on the mechanical behaviour of these fibres needs to be studied in order to determine a baseline mechanical resistance to ensure that the material will remain rigid and not settle.

In the present work, the influence of water dosage on the thermal and mechanical properties of cellulose fibre insulation manufactured through the wet-spray method was studied. The interactions of the fibres with water were first considered with dynamic sorption testing. The drying behaviour of projected cellulose insulation samples was then investigated. A method to test the compression resistance of the cellulose fibres was devised to study the influence of initial moisture content on its mechanical properties. The same was done with thermal conductivity testing via the guarded hot plate method.

2. Material and methods

2.1 Manufacture and preparation of samples

Cellulose fibres of the brand Univercell Comfort were provided by SOPREMA (Bordeaux, France). The raw materials are pre-consumer newsprint paper from several providers from the south of France. In factory, the papers are ground into smaller fragments, which are then turned into loose fibres via a specialized fiberizer. Boric salts are then added as a fire retardant and antifungal agent. The fibres come compacted in a bag in order to optimize transportation costs. Once delivered onsite, the compacted fibres are fed to the blowing machine, which first separates them so they can be blown. A separate pump, connected to the blowing hose, pumps water which is then atomized through nozzles at the same time the fibres are blown into the cavity. In order to vary the initial moisture content of the samples, the pumped spray water pressure varied from 6 to 25 bars. The fibres were blown into wooden moulds of dimensions: 300x300x90mm^3 for mechanical tests. The moulds were fitted with a removable 2.5mm rigid cardboard base covered with a coat of vinylic glue. Once the insulation sample was dry, it was carefully unmoulded and another 2.5mm cardboard was glued to the other side of the sample. Once the glue dried, the sample was then cut into nine 100x100x90 mm^3 pieces via a circular saw. The use of cardboard served two purposes: to ensure that the 100x100mm² samples have good contact with the compression plates and that they were cut evenly without loss of the material. Thermal conductivity samples were projected on 150x150x50mm^3 moulds with a removable top for unmoulding. Once dry, samples were carefully separated from the moulds using a trowel. All samples were stored in a climactic chamber at 25°C and 60% relative humidity (RH). To measure the drying of CFI, the mechanical testing samples were weighed daily in order to measure the evaporated water until equilibrium moisture conditions at 60% RH (a mass variation of less than 1% in 24 hours) were reached. The equilibrium moisture content was then determined by taking 3g of fibres from the ambient dried sample and drying them at 100°C for two hours. Using the mass of the samples and the equilibrium moisture content, the initial moisture content as well as the drying of the material at 24 hour intervals was determined.

Fig. 1: 300x300x90mm^3 sprayed samples (left) and cut 100x100x90mm^3 sample for compression testing (right)

2.2 Dynamic vapour sorption

Sorption isotherms were made by dynamic vapour sorption apparatus DVS Advantage from Surface Measurement Systems Ltd (London, United Kingdom). Loose fibre samples were placed into an aluminium sample holder connected to a microbalance. The samples were then subjected to a series of relative humidity variations from 5% to 95%, with 10% intervals, at a constant temperature of 25°C. The variations in mass due to moisture adsorption and subsequent desorption were then plotted against relative humidity.

2.3 Mechanical testing

Compression tests, adapted from the standard EN 826, on the cut 100mm x 100mm x 90mm samples were made by means of an H5KT universal testing machine from Tinius Olsen (Surrey, England) equipped with either 100N or 500N sensors, depending on the material's resistance. Steel 100 x 100 mm² compression plates ensured direct contact with the samples. Compression was done at a speed of 10 mm/min. A pre-charge of 1 N was applied to ensure direct contact with the sample. Due to the fact that the material is highly compressible, no fracture or rupture was detected so instead the measured stress at 5% and 10% strain was logged for each sample. Compression tests stopped once 20% strain was reached. Since each sample had slight variations in dimensions of the order of ± 2mm, they were measured in order to accurately calculate their respective stress and strain.

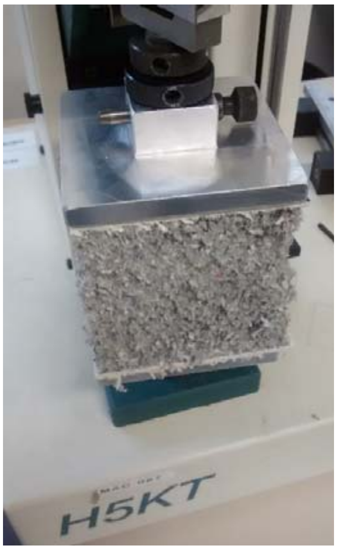

Fig. 2 compression testing setup

2.4 Thermal conductivity measurements

Thermal conductivity measurements were done according to the standard NF EN 12667.
Samples of 150x150x50mm^3 were placed in a λ-Meter EP500e guarded hot plate apparatus from Lambda-Messtechnik (Dresden, Germany). Foam insulation was used around the samples to ensure the contact plates measured only the 150 x 150 mm² surface of samples. The contact plates applied a pressure of 50 Pa to ensure direct contact with the samples without compacting them. Measurements were made at 10 and 25° C average temperature with a temperature difference of 10°C between plates. Steady state was assumed to be reached when the value of thermal conductivity varied less than 1% in 60 minutes.

3. Results and discussion

3.1 Dynamic vapour sorption

Results from dynamic vapour sorption of cellulose fibres are shown in Figure 3. The isotherms show little hysterisis, less than 2% difference between sorption and desorption isotherms. One can see that in the hygroscopic range moisture sorption reaches around a maximum of 20% mass so the range of minimum water dosage of 40%-60% means that water within the cellulose after spraying is contained within the pores. It is possible however, to estimate the moisture sorption in the whole range using mathematical approximations. Many models exist such as Brunauer–

Emmett–Teller (BET) or Guggenhein, Anderson, de-Boer (GAB) models, but for porous solids such as cellulose it is recommended to use the Oswin model: [12]

$$X_e = b_0 \exp\left(\frac{b_1}{T}\right)\left(\frac{a_w}{1-a_w}\right)^{b_2} \tag{1}$$

Where X_e is the calculated moisture content, a_w the relative humidity, T is the ambient temperature, and b_0, b_1, b_2 are coefficients dependent on the material. These coefficients were determined by minimizing the standard deviation between the calculated values and the average between the measured sorption and desorption values. The Oswin model shows good relation with the values determined experimentally. The moisture content at saturation can be estimated when RH values approach 100%. At a RH of 99.999% the Oswin model gives a value of 279% moisture content, showing that, past the hygroscopic range, cellulose can absorb high quantities of water via capillary conduction.

3.2 Drying of cellulose insulation samples

The drying curves of projected 300x300x90mm^3 samples stored in 25°C at 60% RH with varying water pressure are shown in Figure 4. Evidently, an increase in water dosage increases the time for the material to reach an equilibrium dry state. In practice, installers of cellulose fibre insulation consider that when the material reaches around 20% moisture content, it is considered dry enough to allow the installation of a vapour barrier and drywall. For example, a water dosage of 70% can increase the time to reach 20% moisture to 58 hours versus the 19 hours needed when the minimum recommended dosage of 40% is applied, over three times the standard waiting time. It is worth noting that this applies only to 90mm thick insulation at the constant conditions of 25°C at 60% RH. In reality, the drying rates vary depending on thickness and ambient conditions. The thicker the specimen, the colder and more humid drying conditions are, the longer the drying times, which sometimes cause unacceptable delays in a construction project.

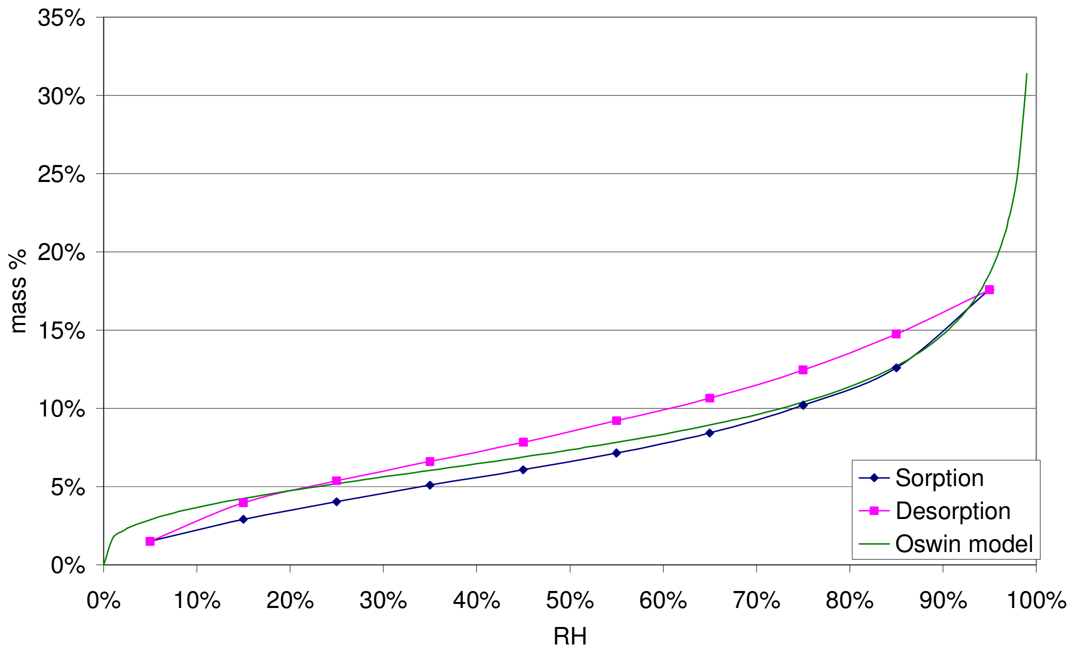

Fig. 3: Sorption and desorption isotherms, with Oswin model approximation

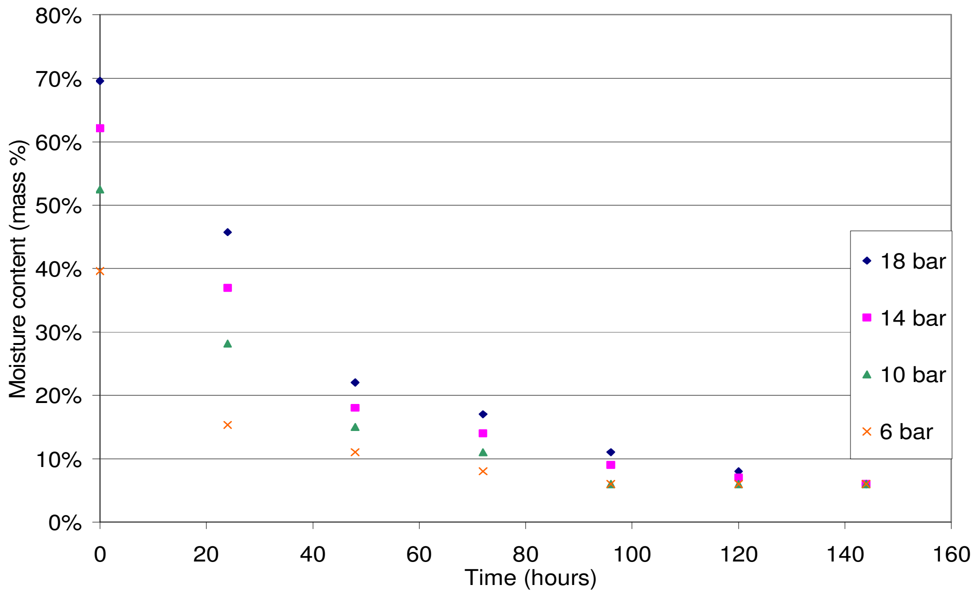

Fig. 4: Drying of cellulose samples, with varying water pressure

3.3 Changes in density.

As is shown in Figure 5, the final density of the material depends on the installed moisture content. The values shown are slightly higher than those found by Salonvaara et. al.[3]. At the minimum moisture content of around 40%, density varies from 50 to 57 kg/m3. The results show a linear increase of density with initial moisture content up to 77 kg/m3. The increase in density has two likely causes: the increased pressure from the pulverised water, which causes compaction of the material as it is projected, and the strengthening and hardening of fibres as they dry. This further emphasises the need to control of water dosage since as the density increases, more of the material is used to insulate the same volume, which subsequently increases costs of installing the insulation. As it has been shown with other natural building materials [13, 14, 15] these variations in density can also cause changes in the thermal and mechanical properties of the material, as will be shown in the following sections.

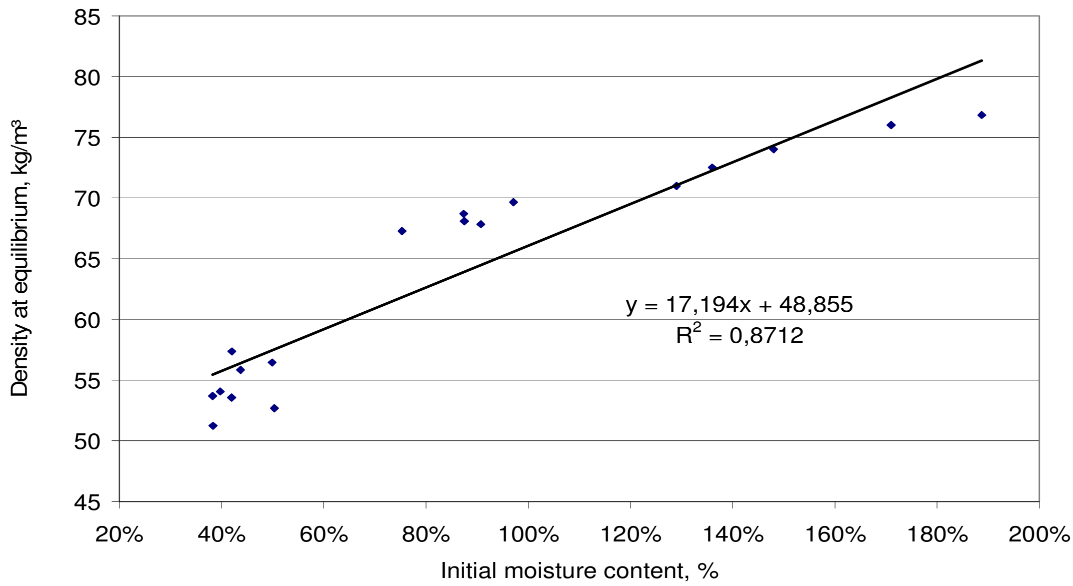

Fig. 5: Influence of installed moisture on final density at equilibrium, with linear regression line

3.4 Compression tests

Stress-strain curves of cellulose insulation with samples with different moisture dosages are shown in Figure 6. The lightweight material shows a quasi-linear elastic behaviour with no rupture at strains up to 20%. As was expected, the material shows an increase in its mechanical resistance with increasing moisture content.

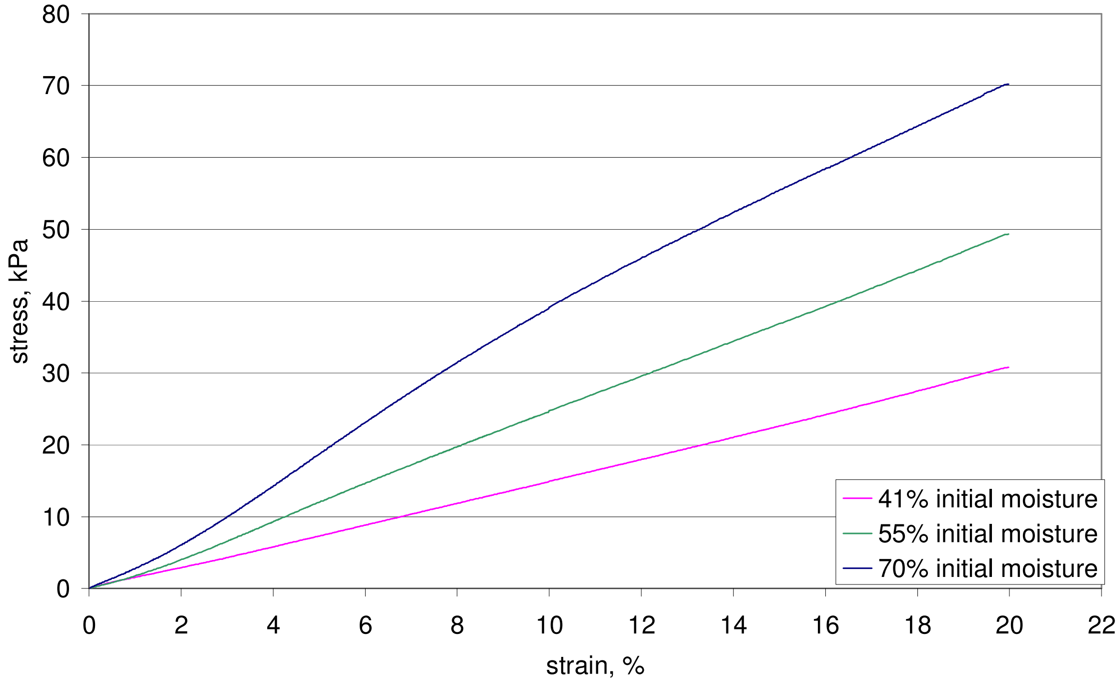

Fig. 6: Stress-strain curves of projected cellulose insulation samples with varying moisture content

Figures 7 and 8 show the relation between water content calculated elasticity modulus E, and the calculated stress at 5% and 10% strain ($\sigma_{5\%}$ $\sigma_{10\%}$) respectively. While all the values show a good linear relation with moisture content, the best indicator seems to be the stress measured at 10% strain $\sigma_{10\%}$. This could be due to the fact that as the material is compacted, the heterogeneous voids within it are filled, giving a more linear and constant reading of the applied stress at higher deformation.

In order to define a « minimum resistance » of wet spray cellulose insulation to ensure that the material will not sag or tear once projected, the measured values of the modulus of elasticity E and compressive stresses $\sigma_{5\%}$ $\sigma_{10\%}$ at around 40% moisture content are averaged. This gives an average of 14.05 kPa, 0.62 kPa, and 1.34 kPa for E, $\sigma_{5\%}$, $\sigma_{10\%}$ respectively. These values could potentially be used as a reference point if, for example, a raw material (recycled newsprint) of different quality is used, or if the amount and/or type of additives are changed.

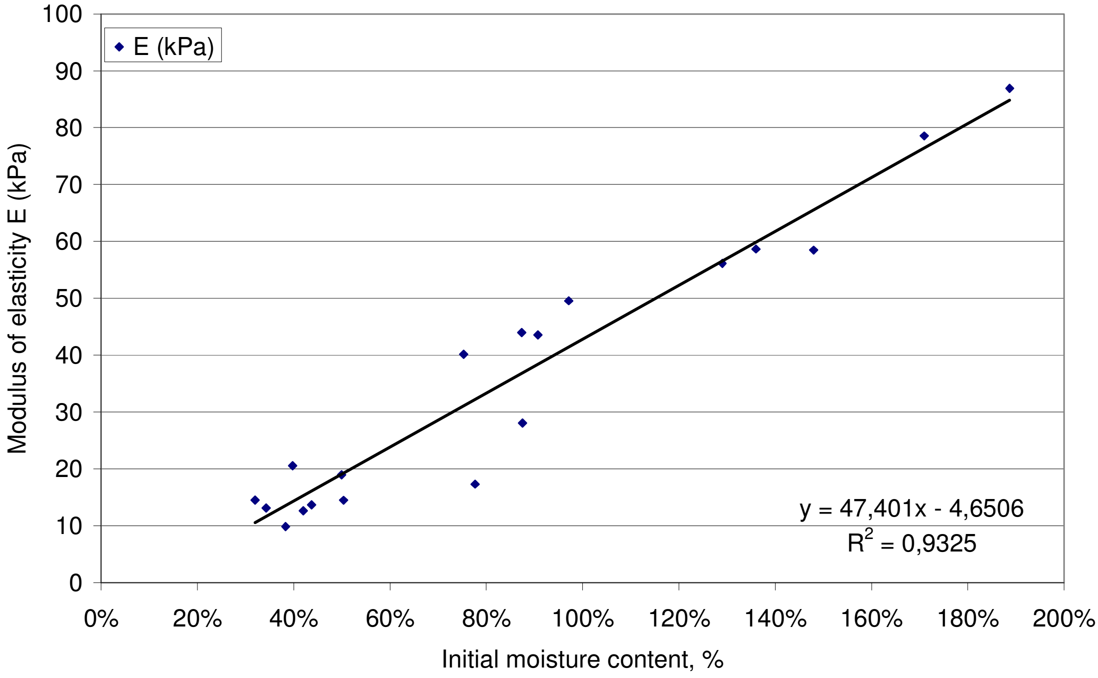

Fig. 7: Influence of installed moisture content on modulus of elasticity E, with linear regression line

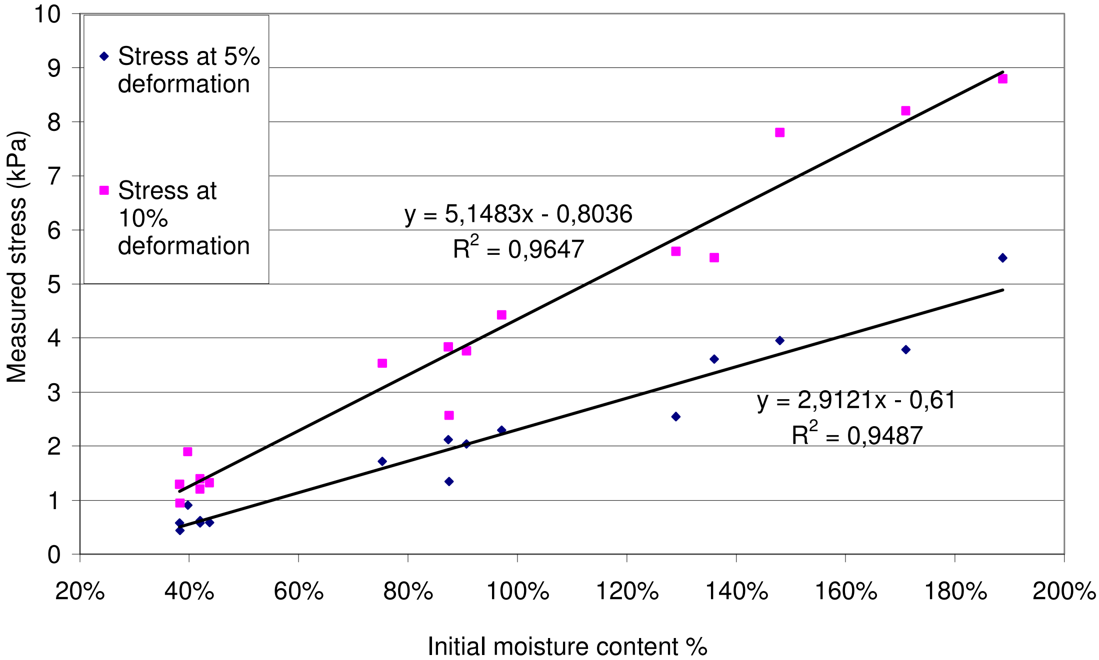

Fig. 8: Influence of installed moisture content on $\sigma_{5\%}$ $\sigma_{10\%}$, with linear regression line

3.5 Thermal conductivity testing

Figure 9 shows the variation of dry thermal conductivity at with installed water dosage average temperatures of 10°C and 25°C (λ_{10} and λ_{25}). As with mechanical properties, the value of dry thermal conductivity also increased with installed water content, although in this case there the difference is much smaller, making the results more prone to inconsistency. Thermal conductivity values varied from 37 to 43 mW/m.K, for measurements made at 10°C and around 40 to 46 mW/m.K for 25°C . These values are comparable to traditional insulation materials such as mineral wool. The high scatter could be due to the heterogeneity of the samples, or to loss of heat through voids between the contact plate and the sample. Since the material is highly compressible it was difficult to ensure perfect contact between the plates and the samples without compressing the samples, which would increase its density and thermal conductivity. While this increase in values of λ with applied moisture content is slight, it is still unfavourable to a wall's thermal performance. It is in the cellulose installers' best interest to use the lowest feasible water dosage in order to ensure optimum insulation capacity of the material.

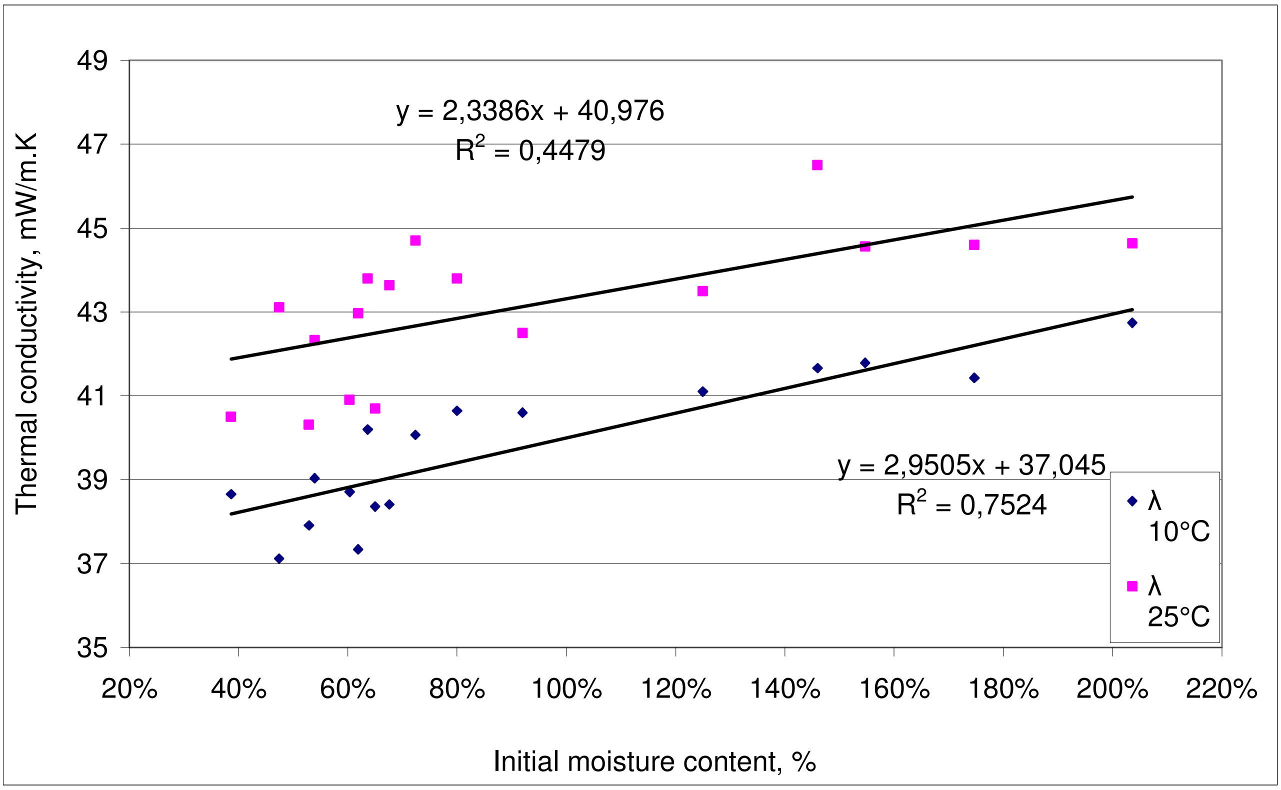

Fig. 9: Influence of installed moisture content on thermal conductivity values λ_{10} and λ_{25}, with linear regression lines

4. Conclusions

As the results have shown, the increase of water not only delays construction after installation, but also increases the density and thermal conductivity wet sprayed cellulose insulation. The increase in density and drying time with increased water dosage remain important factors to consider when applying cellulose insulation. A method to determine the mechanical behaviour of wet sprayed cellulose was devised. The compression tests give an indication of how the installed moisture content strengthens the material in order to prevent sagging or tearing of the material. A baseline of 14.05 kPa modulus of elasticity E and 0.62 kPa, and 1.34 kPa for E, $\sigma_{5\%}$, $\sigma_{10\%}$ was defined as an approximation of the minimum resistance of the material (at ambient humidity conditions) to prevent sagging. While the changes in thermal conductivity could be considered insignificant, there is still a loss in thermal efficiency of the material once an excessive amount of water has been used. In a practical sense, it would be pertinent to have a quality control system which the wet spray water dosage was measured in a test sample before applying to an entire wall. This will ensure that the minimal dosage (40%) of water is employed in order to reduce drying times, minimize density and thermal conductivity, while maintaining a rigid material that will not settle or tear.

Wet spray technology not only applies to cellulose fibres, but new methods of spraying hemp and flax fibres are being implemented for the installation novel eco-friendly building materials, and it is important to ensure that they are installed in the most efficient manner. It is through proper knowledge and testing of these innovative and eco-friendly materials, which will make them more prevalent in the building sector, thus helping reduce carbon emissions of new constructions and renovation projects.

5. Acknowledgements

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The Future of Urban Development in Egypt under the Impact of Water, Fossil Fuel Energy and Climate Change Barriers, Green Infrastructure and Renewable Energy as Sustainable Urban Development Approaches

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Summary

For several years, the process of urban development (UD) in Egypt has witnessed new barriers, first the water shortage, Egypt has reached a state where the quantity of water available is imposing limits on its national UD, Second the fossil fuel crisis, Egypt depends mainly on fossil fuel to generate electricity, Egypt doesn't produce enough energy to meet demand, and it lacks the hard currency to import fossil fuel, finally the Climate Change is another barrier which is usually neglected or concerned as a secondary priority. The study hypothesis that the employing of Green infrastructure (GI) and renewable energy (RE) together as approaches for future sustainable urban development (SUD) in Egypt can overpass the new barriers and achieve UD sustainability. This hypothesis is based on the results of various cases of using (GI) and (RE) as new approaches that support the seeking for SUD in developed and developing countries as well.

This paper discussed the nexus between GI, RE as new approaches for SUD and water shortage, fossil fuel crisis, and climate change as the new barriers that hinder the progress of SUD in Egypt. This paper used qualitative methods by analyzing case studies, and quantitative methods through statistical data, Etc., the study analyze and evaluate several varies cases of UD that seeks sustainability by using GI and RE as new urban approaches to clarify: why and how to use GI and RE as SUD approaches under the impact of the new mentioned barriers, also the other local expected constrains. The local social economic conditions in Egypt are generally representing the common conditions of the emerging countries, that is why the study has selected some cases which represents emerging countries.The results showed the possibility of employing GI and RE as approaches for future SUD in Egypt and to owerpass the new barrires, the cases of study have illuserated why and how to use IG and RE to achive SUD and also how to deal with the local problems in emerging countries such as the bureaucracy of the administrative system, and GI and RE as technical solutions.

Keywords: Sustainable urban development, Water shortage, Fossil fuel energy, Green Infrastructure, Renewable Energy, Climate change

1. Introduction

Egypt is an emerging country that is witnessing a growing economy, and a steadily increasing population besides its common urban problems like other emerging countries, these conditions have led to the phenomenon of the chaotic urbanisation, the government awareness of the need to deal with this urban problem has started early in the mid of the twenties century, during more than five decades the government has adopted successive UD plans, those plans have followed the west and developed countries experiences which were not in line with the local conditions and priorities, also institutions of the government have dealed with the UD global trends such as the need to sustainability for the next generations in shallow way and without enough studies to determine the actual local needs and priorities. Moreover new barriers that can hinder the UD process have appeared recently, Egypt is actually facing a water shortage, and fossil fuel crisis, which mean the necessity to rethink the current strategies and policies that already were not effective to solve the old common urban problems. The study is discussing the need to new national strategies and policies which depends on new approaches of SUD planning, the study results were extracted from the study cases, these results represented how and why to employ GI and RE in the SUD plans as lessons from practices.

2. Urban development in Egypt, an overview

UD in Egypt is the product of the UD planning process which adopted and conducted by the institutes of the government, this process (which was in accordance with modern accepted concepts till the late decades of the twenties century) has started early in Egypt through the second half of the nineteenth century [1]. Till the mid decades of the twenties century the urbanisation process was under control by the government, Cairo and other main cities such as; Alexandria and Port said were symbols of the cosmopolitan cities which have attracted the immigrants from south Europe and other Middle East countries [2]. However during the next half of the twenties century and so far, for many reasons (political, economic, and social) the UD process in Egypt has faced many barriers, that led to the current bad urbanism condition, Egypt today is an emerging country [3], the UD plans is still facing the problem of how to deal with the rapid chaotic urbanization. There is a consensus on the current degradation of urbanism condition in Egypt, according to a UNICIEF report: "In the last decades, the expansion of Egyptian cities has been for the most part unplanned, with a growth in informal settlements" [4]. Thus the urban areas in Egypt share the same common characteristics of the emerging and developing countries urbanisation, where the rapid urbanisation process and the slums are significant urban phenomenon, hence, the UD plans in Egypt aimed to keep up with the rapid chaotic urbanisation by adopting a policy of fostering of new settlements in the desert, notably in outskirt of Greater Cairo (GC) also to improve the quality of urban life in the slums, as well to halt the future growth of those slums, these were the main urban aspects to be dealed with through the UD plans till the last decades of the twenties century.

2.1 Sustainability and UD in Egypt

During the last decades of the twenties century the term sustainability has gained widespread usage, In particular when associated with UD, notably after being sponsored by the UN in 1987 through the Brundtland Report [6], but is there a difference between the local and the global response to adopt sustainability in UD? The answer can be obtained by realizing the motivations as follows: First globally, during the eighties of the last century when the term sustainability was appeared, the motivation was due to the need for SUD to improve the urban environment, reduce resource use, and to reduce the consumption thus reducing the waste [7], within the last decade of the 20th century the motivations have changed, the global concern was trended to the global warming and the climate change, In 2005, the Kyoto Protocol entered into force, thus committing the developed country signatories to reduce their emissions of greenhouse gases [8]. Second locally, in Egypt and other emerging and developing countries as well the motivations were always associated to the priorities, thus why the UD plans in Egypt often focus on dealing with the physical urban needs, "Planning exercises for Cairo from the last few decades, up to and including the 2050 vision, are preoccupied with density. They are preoccupied with reducing the extremely high population density of Cairo and the Nile Valley" [9].Therefore the adopted policies sought to: Establishing new urban communities, improving the infrastructure and other urban utilities in both formal and informal urban areas, while the achievement of sustainability come as secondary priority.

So far sustainability as an approach for UD in Egypt is just an academic trend, the official UD plans by the institutions of the government have dealed in superficially way with sustainability, for example; the new GC master plan "Cairo 2050" emblem is Cairo: Global-Green-Connected [5], the term Green was used to denote sustainability, the plan report pointed out to the possibility of achieveing SUD by increasing green spaces ratio!

2.2 The new parries that facing the UD plans in Egypt

UD in Egypt is a dynamic process that responds to local variable and changeable circumstances, till the end of the twenties century UD plans represented a response to the pressures resulting from rapid urban growth, in Egypt the policy of fostering of new settlements in the desert is the most appropriate policy to the circumstances of urbanisation in Egypt, Providing planned areas with well-developed infrastructure is a practical solution to accommodate the urban population growth and at the same time reducing the growth of the slums, but this policy need not only to be funded either through public sector or private sector, but also to secure enough water supply and energy. However as mentioned before, Egypt is facing; water and Energy shortage. Firstly the water shortage; Egypt is facing an annual water deficit of around 7 billion cubic meters. In fact, United Nations (UN) is already warning that Egypt could run out of water by the year 2025 [10]. Water scarcity is a real treat that must be studied, Egypt needs an efficient water management plan that deals with the current and the future SUD needs.

Secondly the fossil fuel crisis, which is causing the current energy crisis in Egypt, simply Egypt depends mainly on fossil fuel for producing electricity, Egypt already have local resources of the fossil fuel but through the last decade the domestic demand has overpassed the production, "Subsequently the consumption of energy has been boosted. As a result, in recent years domestic supplies have fallen short of demand, due to the ongoing increase in consumption, stagnation in production, and a very generous subsidy policy which heavily contributed to increasing consumption" [11]. This new barrier has a direct negative impact on the UD process. So far the climate change has not caused significant physical changes that can affected the UD process directly, but according to varies studies the impact will be significant on the different aspects of life in Egypt, notably the UD process as the urbanisation map will be changed, also the changes are expected to impact the Nile flows which will deepen the water crisis barrier [12], [13].

2.3 The need for new SUD approaches

In light of the above, the achievement of SUD in Egypt is already has been treated by new barriers; that have Its tangible current effects, beside the climate change which can be considered as a future barrier that need a readiness through the UD plans, besides the original existing common urban problems, and the bureaucratic administrative system [14] legislation that governs the urbanisation process, and the social economic conditions, besides the priority need to deal with the existing urban problems, the government through more than five decades has adopted several successive UD plans, varied urban policies and strategies which were changed under the political economic theories thoughts of each era, and was influenced by the prevailing urban theories in the West. Despite the continuous efforts and the changing of urban policies and strategies through more than a half century, yet common UD problems still exist, moreover new barriers have appeared and the UD process in Egypt has become more complicated, also in recent decade more variables were added to the sustainability equation of the SUD in Egypt , In the meantime the institutions of the government understanding of the necessity of sustainability in the UD process was and still a sketchy understanding, the results of the Egyptian experience of dealing with UD process have showed clearly the need for new SUD approaches that are modified to be suitable to the local conditions, according to an official report by the Egyptian Ministry of Planning and International Cooperation, Egypt needs new strategic approaches for the SUD future plans [15]. It is a global trend to look for new approaches for the achievement of SUD, this is an example from EU: "As a basic principle, the European Regional Development Fund (ERDF) should support SUD through integrated strategies that tackle the economic, environmental, climate, social and demographic challenges of urban areas (Article 7 of the ERDF regulation)" [16].

3. GI and RE as SUD approaches

Recently in last few years the trend of SUD has evolved to be integrated SUD, which can be defined as "An integrated plan for SUD comprises a system of interlinked actions which seeks to bring about a lasting improvement in the economic, physical, social and environmental conditions of a city or an area within the city. The key to the process is “integration”, meaning that all policies, projects and proposals are considered in relation to one another. In this regard, the synergies between the elements of the plan should be such that the impact of the plan as a whole adds up to more than would the sum of the individual parts if implemented in isolation' [17]. Such an integrated approach is clearly important to achieve SUD in Egypt case and other similar cases in emerging and developing countries, this approach can ensures the dealing with the various aspects that facing the future of UD in Egypt, GI and RE can be identified as effective responses to the new challenges, that can be used in conjunction with other approaches to deal with administrative problems and the traditional problems associated with the bad situation of urbanisation in Egypt, According to the European commission (EC) "Success in UD can only be achieved through an integrated approach. Hence combining capacities and local knowledge is essential to identify shared solutions and to achieve well accepted and sustainable results' [15].

3.1 The need for modified conceptual definition of GI and RE

Both of GI and RE are global trends that associated with SUD process, but also there is a regional perspective of both of them, and sometimes a local perspective that related to the local circumstances, for example it is hard to find a standard definition by consensus for the GI, indeed there is a general understanding definition of the GI but it varies from arid to humid regions so GI definition in Australia is not the same in UK, also RE, there are many types of RE but the availability of each type is related to the local natural, socio-economic and the techonology avalapility of each country, so far the knowledge and applied technics and data of both GI and RE are produced in the developed world, this is why there is a need for modified conceptual definition of GI and RE to work with in the local aspects in Egypt and other cases of similar conditions.

3.1.1 GI from a SUD perspective for arid regions in emerging and developing countries

GI as an urban approach of the SUD has evolved in the developed world notably in the USA and the UK, Australia, "Holistically the available data about using GI as a design approach or a supporting tool in the urban design process were through theoretical research and implemented projects which were produced in the developed rich countries, notably in the USA, UK, EU and Australia [18]. This is why there is a need for an urban perspective of GI that can deal with the local conditions of Egypt as an arid region in an emerging country, generally GI associated with the management of the storm water, but for the purpose of this study GI in Egypt and other similar cases will mainly focus on the management of water resourses and the wastewater, these will include all the types of wastewater see figure 1, and also the ground water in Delta and Nile valley, hence GI will be considered as a tool to manage water resources through reducing the water consumption, the reusing of the treated wastewater, which can be an important source of fresh water in Egypt, see figures 1,2 “Wastewater can be viewed as a resource of fresh water” says John Sheaffer [19].

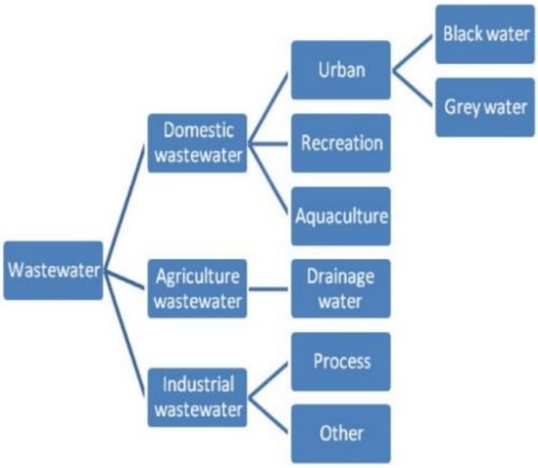

Fig 1. Types of wastewater

Country	Population (in million)	% Urban population	% population sewered	Domestic water supply MCM	Industrial water supply MCM	Treated wastewater MCM
Bahrain	0.570	91.0	65	102.3	10.0	50
Egypt	63.271	45.0	52	3315.0	4600	900
Iran	61.975	59.6	10	4395.0	1215	300
Iraq	20.604	75.2	50	1400	2100	-
Jordan	4.356	72.1	54	230.0	36.0	70
Kuwait	1.687	97.3	90	216.0	15.0	110
Lebanon	3.084	87.7	52	368.0	50.0	6.0
Oman	2.302	38.6	20	75.0	22.0	30
Qatar	0.558	91.8	70	71.0	9.0	25
Saudi Arabia	18.836	80.7	72	1617	200.0	550
Syria	14.574	52.8	55	620.0	280.0	400
UAE	2.260	84.5	85	515.0	200.0	110
Yemen	15.678	34.6	35	221.0	32.0	30

MCM = million cubic meter

Fig 2. Treated wastewater in Egypt and some ME countries in 2010

Currently, wastewater in Egypt represents about 18% of the available water resources, wastewater in this study include: sewage water, drainage water, ground water, reuse of treated wastewater could be increased from 0.70 to 2.97 BCM/year by 2017 [20]. See figure 3.

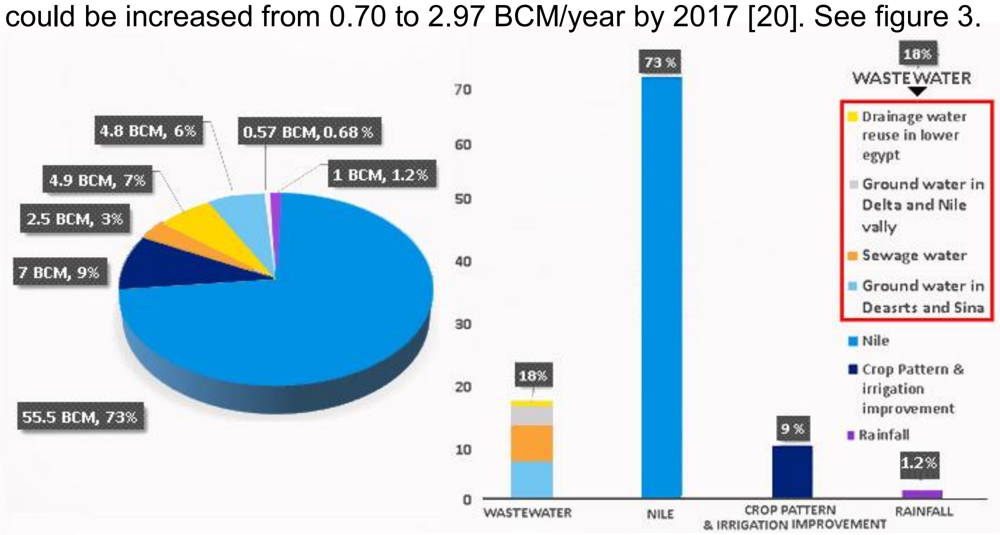

Fig 3. Water resources in Egypt and the importantce of the wastewater

the EC has defined GI as “the use of ecosystems, green spaces and water in strategic land use planning to deliver environmental and quality of life benefits", also GI was defined as "GI is fundamental to urban planning and design frameworks for both new growth areas and redevelopments" [21]. These defenitions have showed that GI is strongly linked to the SUD process, at the meantime GI is an economic development tool, particularly when compared to other conventional tools of UD. Evidence shows that well-designed GI enhances the economic [21], [19]. So through the previous debate GI in this study from an urban perspective for arid regions in emerging and developing countries has twofold; first GI can be an approach to achieve a well management system for water resources, second GI is also an economic SUD approach.

3.1.2 RE from a SUD perspective for emerging and developing countries

UD has been always correlated with increasing demand of energy, this fact has twofold; first the negative impact from the developing and emerging countries point of view which related to the need to provide more budget to meet the increasing demand for energy, second from the developed world point of view the increasing demand of energy will lead to growth of GHG emissions, RE can help decouple that correlation, contributing to SUD, simply RE is the clue for the both cases of developed and emerging developing countries. Though the exact contribution of RE to SUD has to be evaluated in a country-specific context, RE offers the opportunity to contribute to social and economic development, cheap energy access, secure energy supply, climate change mitigation, and the reduction of negative environmental and health impacts [22]. Thus RE can be particularly suitable for emerging and developing countries due to the following reasons; Firstly; costs associated with energy imports can often be reduced through the deployment of domestic RE technologies that are already competitive, but it is important to determine which type of RE is suitable according to each country-specific context, for example in Egypt there are the natural potentials for solar, wind, biomass, and hydro energy [7]. "The Egyptian government started implementing ambitious plans to further expand electricity capacity generated by wind and solar power, particularly to increase wind generations to 7.2 GW by 2020 [22]. Secondly RE can contribute to social and economic development. Under favorable conditions, cost savings in comparison to non-RE use exist [22], see figures 4.

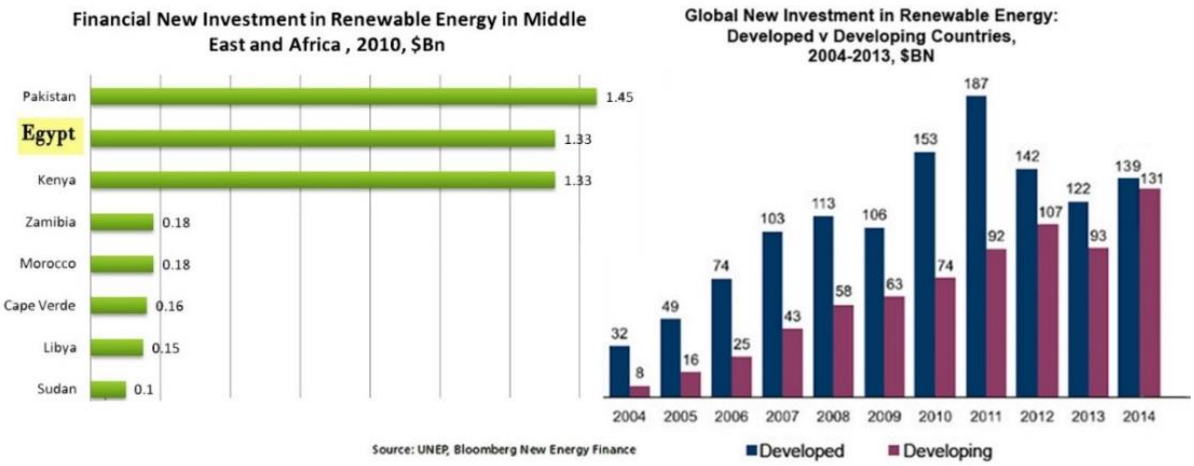

Fig 4. Left, Egypt is considered as a pioneer user of RE in comparison to the ME and African countries, right, growing investments in RE sector, developed vs developing countries.

4. Case studies

Case studies have explored how and why to employ GI and RE as SUD approaches, the cases have covered wide range of the plans level from small scale projects to the national plans level.

4.1 The Shire's Dongara- Port Denison (Australia) GI strategy 2015-2020.

This is a case of GI plan in an arid region, the conservation of using the available water resources was a main target, the Plan identifies the need to develop a GI Strategy, the study case has defined GI as "the network of green spaces and water systems that deliver multiple environmental, economic and social values and benefits". The strategy of the plan will ensure that the Shire leads by example by reducing water and energy consumption, and by implementing efficient and innovative systems, projects and initiatives, the plan depends on a strategic approach that can guide a wide variety of public sector. The main aim is to improve the quality of life through developing an integrated network of multifunctional green spaces [23], as the region is an arid region the water management by the GI plan was initial. The local council has adopted some policies to achieve the plan aims, in particular to face the water shortage. First, a policy for existing public open space purpose, through rationalizing the Shire's public open space reserves to reduce ground water use by grouping types of vegetation into categories with similar water requirements [23], see table1 .

Table 1: Water Conservation Requirements

Max volume of water per year	Each area of public open space must meet the following requirements: **Type of POS**
10,000 kl/ha/yr	High use, high profile
7,500 kl/ha/yr	Low use, high profile
6,000 kl/ha/yr	Low use, low profile
0 kl/ha/yr	Dry areas of POS, parks and bush

Second, a policy for water sensitive urban design. This case has clarified how GI can be employed as an SUD approach, and also has showed an example of the possibilty of using GI principls to face water shortage in arid regions by implementing stratigies and policies that aim to conserve and manage the consumption of the water in publc sector.

4.2 Reusing wastewater in Singapore (dealing with water scarcity)

Singapore is a unique case of water management that is in line with the SUD goals, the long strategy of dealing with water shortage crisis is a good example of GI principals that seeks to the achievement of SUD. Singapore is a city state in challenging environment of a densely populated island, innovative integrated water management approaches were adopted such as the reuse of wastewater, in order to reduce the country's water shortage. Singapore's approach does not rely only on physical infrastructure, but it also emphasizes proper legislation and enforcement, water pricing, public education as well as research and development [24]. The national water resource development strategy that was adopted is the key to success. This strategy relies on four water sources, called "the four taps", the tab that correlated to the purpose of this study is third tab which is; wastewater or reclaimed water as known in Singapore, (producing what is called NEWater) (up to 115 million imperial gallons (520,000 m3) per day, NEWater is the brand name given to ultra-pure water that is produced from Wastewater [24]. The key points of the Singapore experience are:

- Political Will.
- Institutional Integration.
- Integrated Land Use Planning.
- Enforcement of Legislation. Strict implementation of legislation such as pollution control is another essential characteristic of water management in Singapore.
- Public Education. School education and public campaigns.
- Application of advanced technology.

As of 2008, according to PUB NEWater was able to meet 30% of water requirements [25]

4.3 10% RE goal, the case of Cape Town, South Africa

This is a case of a city level project, the importance of this case that it has showed how to fund RE projects by international collaboration, encouraging private sector. As part of Cape Town's Integrated Metropolitan Environmental Policy (IMEP), there was a strategy sets out a number of vision statements, targets and timeframes. One of the targets is to source 10% of its energy from

RE sources – which would include solar and other forms of energy – by the year 2020 [26]. Currently, Cape Town generates very little of its own electricity, purchasing most of it from the national electricity grid which is dominated by coal-generation plants. The city has a wealth of untapped RE resource potential – in wind, photovoltaic, solar thermal and also potentially tidal wave power. Which can be used in pursuit of its goal to source 10% of its energy from renewable sources by 2020 [26].

4.4 RE, the case of China

The energy policy of China matters globally. The country is the largest energy user in the world, In 2013, China led the world in RE production, with a total capacity of 378 GW, mainly from hydroelectric and wind power. As of 2014, China leads the world in the production and use of wind power, solar hotovoltaic power, and smart grid technologies [27]. The national energy policy in China has focused on the RE solutions, as the government is considering RE as a source of energy security, not a question of GHG emmission reduction, thus why the government of China has followed a strategy for a diverse mix of RE in the power sector, Currently, 20% of the country's electricity comes from RE. Under the business-as-usual scenario, this will rise to 30% in 2030 [30], through the diverse mix of RE which include:

- Hydro: China's hydroelectricity potential by 2030 is 400 gigawatts-electric (GWE).
- Wind: Wind became China's second largest source of renewable power in 2013 and has potential to grow further, from 91 GWE in 2013 to 500 GWE by 2030.
- Solar PV: China installed 13 GWE of solar PV capacity in 2013, and has potential to grow further to 308 GWE by 2030.

The Chinese government is implementing multiple policies to promote RE. From 2008 to January 2012, China held the top spot in clean energy investment. The RE Law passed in 2005 explicitly states in its first chapter that the development and the usage of RE is a prioritized area in SUD need of energy [28]. The Twelfth Five-Year Plan, the current plan, also places great emphasis on RE, detailed incentive policies and programs include the Golden Sun program, which provides financial subsidies, technology support and market incentives to facilitate the development of the solar power industry; the suggestions on promoting wind electricity Industry in 2006, which offers preferential policies for wind power development; and many other policies [28].

5. Conclusion and Discussion, Lessons from practice

The new barriers of water shortage and fossil fuel that is facing the future of SUD in Egypt can be reduced or even to be totally eliminated by following new approaches for UD plans, hince to rethink the current national strategies and policies of SUD, the case studies have showed that the employment of GI and RE as urban approaches for the UD plans can solve such problems like the water shortage and the need for clean affordable energy resources, at the same time the principals of GI and RE are already closely linked to sustainability which usually come as secondary priority in the case of emerging developing countries. However the cases have clarified that the achievement of sustainability aims and other barriers needs an integrated SUD vision that is depends on many varies approaches such as social and economic approaches to support GI and RE as main approaches. The study results represented lessons from practice that illustrate how and why to use GI and RE as urban approaches for UD plans though strategies and policies that not only deal with the GI and RE but also deal with other expected barriers which related to the emerging developing cases such as; dealing with advanced technical solutions, and the bureaucracy of administrative systems. The results can be divided into three categories; Firstly General lesson: There is a necessity for hard policy decisions and to reconsidering the legal regulations that governs the UD process in Egypt. The need to not to rely on only the physical and technical solutions, but also to emphasizes proper legislation and enforcement, other social and economic approaches as well as scientific research and development like in Singapore case. Emerging and developing countries can go beyond funding problems by diversification of funding sources, such as international collaboration, encouraging private sector through new innovated funding deals that make benefits to all the stakeholders, like the case of Cape Town. Seconsly GI lessons from practice: The cases clarified how GI can be employed as an SUD approach, and also has showed an examples of using GI principls to face the water shortage in arid regions like in Shire's Dongara case, also to reuse wastwater as a water resource like in Singapore case. These are stratiges and polieces which were extracted form cases to face the water shortage; Governments need to have a national aim that can be achieved by a political will, the enforcement of legislation. Strict implementation of legislation is another essential characteristic of water management. To implement stratigies and policies that aim to conserve and manage the consumption of the water in publc sector as a first step, wastewater becomes a new water resource, particulary in high populations countries that generate high amonts of wastewater, "A healthier future needs urgent global action for smart, sustained investment to improve wastewater management" (UNHABITAT, 2010). Successful and sustainable management of wastewater requires a cocktail of innovative approaches that engage the public and private sector. Planning processes should provide an enabling environment for innovation. Finally RE lessons from practice: RE will be a compulsory trend not only in developed countries but also in emerging developing countries, RE strategies and policies can be on both, the level of a project in a particular region or city like in Cape Town case or national level like the Chinese case which represented a practical case to deal the RE as an SUD approach, China has managed to led the world in RE production through a national energy policy that has focused on the RE solutions. Cosedring RE as a source of energy security has played a role in the successive of this case. Also the Chinese experience is suitable for emerging and developing countries which still adopted a financial subsidies policy for the fossil fuel products like in Egypt, it will be better and efficient to provide this financial subsidies to encourage technologies that support and market incentives to facilitate the development of RE. The following of a strategy for a diverse mix of RE in the power sector.

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The geocooling, bioclimatic solution to conventional air - conditioning for existing residential building

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Summary

In the present paper, we propose to progress knowledges about integration of geothermal energy into existing building by earth / air heat exchanger to improve thermal indoor environment in summer days. In order to study the cooling potential with this system, our choice was focused on an individual house located at Tizi-Ouzou town. Referring to local's conditions, physical data related to the ground and building envelope, we use **Scliab** as a platform for simulation implemented in a modular environment. It acts on a representation of the mathematical function in form of block diagrams. The result obtained by present simulation, allows choosing of the most powerful configuration of the exchanger.

Keywords: conventional air-conditioning / ventilation /renewable energy/ thermal mass / energy retrofit

1. Introduction

During the last decades, the increasing of Algerians' living standards is accompanied by a rise of thermal comfort requirements inside building especially in hot summer days. Yet, unresponsive recourse to air conditioning systems involved strong fossil energy consumption accounting for 40% of national production [2; 17; 20]. This measurement induces a growth in electricity consumption by + 11 % in 2013 [2, 20]. It is so possible to consider the pressure on the electricity production networks, especially the problems raised by estival peak demand [8].

This fact is due to fast production of housing with low cost and unconscious design which ignor the climatic aspects [20]. Even more, the development of building industry process (neglect of thermal mass in building envelope) increased considerably the relation between indoor environment and the external climate whose problems of overheating arose with acuity [5 ; 6].

Countries concerned by reducing conventional air-conditioning demand and it harm full effect on environment while maintaining thermal comfort; have developed more concretely the bioclimatic strategies. This approach is according to wich "energy efficiency" [10].

In spite of its institution by regular way, the energy efficiency is ignored in Algerian building sector during design process [20]. Also, Construction of new buildings provides an opportunity to adopt energy efficient design and implementation of green technologies [13]. But, the energy retrofit of existing households numbered some 7.755.584 in 2013 conceals a significant potential in energy saving, taking into account the significant number of the residences by reducing energy demand. It acts on careful appropriation as well adequate architectural and constructive measures (reduction of the solar and internal gains, access to the thermal mass), as development of passive cooling techniques. In addition to that, exisiting buildings can not function only on passive systems. It may be possible to use mechanical equipment and integrate new technologies when necessary, if it is used to increase the performance of the system [7].

As building envelope improves, there is a rising interest for summer cooling systems based on renewable energies. One of them consists in forcing air from outdoor through an air-soil heat exchanger [7]. This system is often applied in hot climate to reduce cooling loads of building.

2. Methodology

Cooling demande for comfort perposes in building is mainly due to climatic conditions. Other important factors are:

- Regional climatic conditions: temperature and humidity differences depending on geographical position. The predominating factors is usually the out door air temperature.
- Urban climatic conditions: the climate in densely built areas cans differ from the surrounding climate, for exemple in temperature, wind speed and humidity.
- Building design: the architectural ans structural design features of building have a strong impact on its indoor climate (building layout, insulation, windows positions).

In the worldwide when the energy crisis of the seventies years aroused interest in the use of renewable energy as a substitude of conventional fuels in building. This interest was directed to the use of solar energy for heating. This led to the development of active solar systems. In time spaces heating shifted to passive systems, but still the emphasis was on heating. Only about 1978 did more worldwide interest arise and systematic research strars in passive cooling [7].

Cooling of building by passive and low energy systems can be provided through the utilisatiion of several natural heat sinks such as the ambient air, the upper atmosphere and the under surface soil [15].

2.1 Global warning in Algerian context: households footprint

Algeria is highly vulnerable to climate change. The analysis of climate data from 1931 to 1990 in northern Algeria reveals a rise in temperature of 0.5 °C would reach an increase of 1 °C by 2020 [14]. The effect of overheating espicialy in urban area could induce an increase in the electricity consumption for air-conditioning about 141%. However, the growth of air temperature by 1°C as daily average value requires approximatively 8MW electric power for cooling [19].

The challenge of planning and the energy consumption for air conditioning are only the initial impacts to which Algeria must find answers [17]. By adhering to the Kyoto Protocol in 2005, Algeria has developed an initial strategy against climate change and developed numerous projects for adaptation and mitigation of changes climate. The national strategy is based primarily on four areas: institutional strengthening, adaptation to climate change, mitigation of emissions of GHG and human capacity building [14].

The actions selected are primarily the housing sector that is very energy intensive, more than 40% of the electricity consumption [2]. The "Energy Efficiency" program includes measures to the rationalization and energy conservation. This program contains actions that favor the use of forms of energy best adapted to different uses and require behavior change and improvement of equipment.

In this way, the concept of "energy saving" adopted by the law 99-09 was promulgated in order to stage with these threats. This concept covers three dimensions[1]: the rational use of energy, the development of renewable energies and reduce harmful effects of conventional energy system on environment. However, this law considers only the new building and neglect the existing households estimated at 7.755.584 in 2013.

Furthermore, the proposed shares of energy efficiency include the introduction of the thermal insulation of buildings that will reduce about 50% the energy consumption for heating and air conditioning and use of energy efficient equipment. This action will avoid about 40 MT CO2 to 2025. However all these measures do not allow substantially reduction of the current level of GHG emissions. The estimated reduction impacted by these measures account for 10 to 12% [17].

2.2 Passive cooling by under surface soil

The use of the ground for cooling buildings has gained an increasing acceptance during the last years [15]. This concept is not a new idea, the use of this technical goes up from old civilizations which have already using hypocaust (old American civilization), old system of heating and air conditioning by the ground, in Greece (2500 befor J.C), as welle as in Moroco[19]. After that, it was discovered in Tibet (installed for the heating of the baths, under the beds and for the whole buildings). At the 1st century af J.C, we can note the presence of two systems: Hypocaust of the Roman's civilisation and Ondol in Korea. It acts to circulate a hot air in a basement, and then was abandoned after the fall of the Roman Empire [16].

In fact, a similar technique was already employed) in XVI century as natural cavities to refresh a group of villas in Costozza (Covolis- Italy) [18]. This system of cooling by the ground is connected to building by mean of underground galleries, [19]. This system is very similar to Malqaf (Wind cartcher), mainly widespread in the hot and arid climates, in particular the Middle-East (Pakistan, Iran, Yemen…) [3].

Recently, a renewed interest for this technique is observed in the construction, often accompanied with the air/ground heat exchangers [8]. Research on the air-to-ground exchangers seems to have started after the oil crisis of 1979 and to have stopped temporarily after the second energy crisis of 1985. Until 1995, some researchers resumed studies on the questions of the performances of the air-to-ground exchangers, their thermal behavior and their integration to the building like system of preconditionning of the air [21].

The principal of this system is directly related to the thermal proprieties of the ground especially thermal inertia. It uses the solar energy stocked in the surface layers of the earth's crust [5]. The nearly constant ground temperature at a certain depth has been regarded as a passive means for cooling of buildings by several researchers [4]. It has been observed that the ground temperature at a depth of about 1.5 to 2 m remains constant throughout the year and is equal to the annual average temperature of a particular place [5].

During the cooling period, the ground has a temperature lower than the ambient air. A building can be indirectly coupled to the earth by means of earth pipes. When cooling is desired, air introduce into building has been previously circulated underground by means of earth to air heat exchanger (Fig.1) [12].

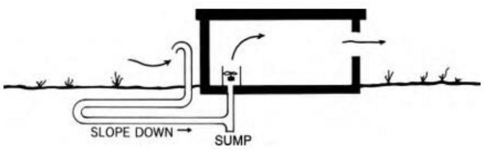


Fig.1. Indirect earth cooling is possible by means of tubes buried in the ground [12].

[1] Law 09-99 of 28july1999, relative to energy savin: official journal of ALgerian Republic n° 51of 02/08/1999

Earth to air heat exchangers consist of pipes buried in the ground where air is forced in order to be cooled and then circulated inside the building. To get the maximum cooling effect, pipes should be buried as deeply as possible to take advantage of that constant, deep-earth temperature, which is the coolest available in the summer [12]. Deep below the surface, the soil is also more likely to be moist during the summe [9]r. Nevertheless, very long pipes are needed to cool a building [12].

The greatest problem with earth pipes is condensation, which occurs mainly in humid climates where the earth temperature is frequently below the dew point, or saturation temperature, of the air. The pipes, therefore, must be sloped for water to drain into a sump for removal [12].

This combination must be thought like integral part of the building and not as a system to be added with this one. It may be possible with a careful improvement of envelop prorporieties such as inertia, solar protections and the management of the internal loads (lighting, apparatuses,..), as well as an estimate of the electric consumption of the auxiliaries.The use of this system requires a difficult dimensioning process which involves optimisation of various parameters such as the airflow vilosity, pipe length, depth and pipe diameter [5].

2.3 Description of the case study

The case study presented in this paper is about a building which presents similar building characteristics to many houses in Algeria. The house chosen for this study is located in South-Western of Tizi Ouzou state at mean altitude 180m. It is situated at Northern latitude of 36°4', eastern longitude 04°03'. The house is sitting in a contemporary estate sector, with average density, characterized by the establishment of pavillonar constructions type varies between R+0 and R+2 (C.E.S: between 0.5 and 0.9, the C.O.S: between 1 and 2.7). It is developed on one level; built on a buried semi cellar, and covered by an accessible roof terrace. It is open on the street by the South-eastern elevation and on a yard by the North-western elevation.

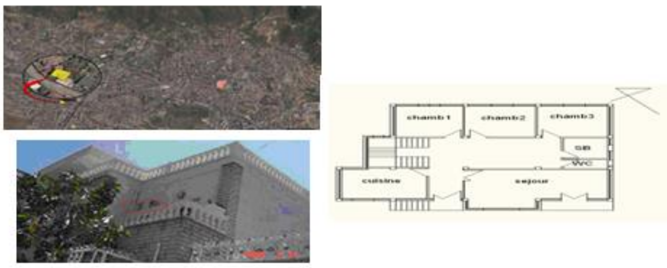


Fig.2. geometrical configuration of house

2.4 Climatic analysis of site

According to the classification given by architectural recommendations, the town of Tizi Ouzou is caraterized by a temperate Mediterranean climat. It is located in in the zone H1a winter and E1 for summer:

- H1a is subject to the influence of the sea (littoral - sea, altitude < 500m), characterized by one hard winter with low daily amplitudes
- The zone E1, it is subject to the influence of the sea whose hot and wet summer the variation of the diurnal and night temperatures is weak.

However, this climate is subjected to microclimatic conditions related to topography and morphological configuration of the site. Yet, the mountains surrounding the site contribute to overheating. The fresh air coming from the sea is stopped by relief. In addition to that, the presence of water dam (Taksebt) has contributed to evolution of moisture rate in air. The fog induced by evaporation contributes to the evolution of humidity rate and consequently creating an intolerable situation in summer.

According to climatic data provide by ONM, in figure 3 we presente a synthesis of monthly mean temperature in shade at Tizi Ouzou on a period of 10 years These data were plotted in the bioclimatic chart. Givoni psychometric diagram is very useful for any architectural design that relate to environment and climate balance. In fact, it consists in the first stage, dealing with climate and environmental conditions. Consequently, it helps designer to identify measures needed to maintain the indoor environment inside the comfort zone. These measures may be achieved by adopting architectural design to take advantages of the climatic elements (passive methods). When this method is not sufficient, mechanical means, active methods are necessary by using energy sources external to the building envelope.

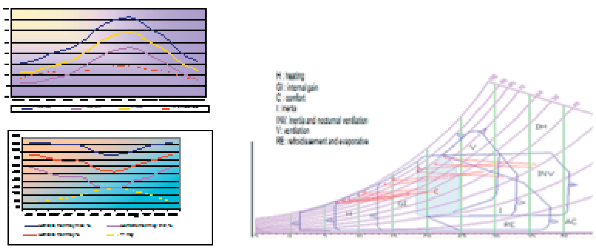


Fig.3: psychrometric diagramm of Tizi Ouzou

2.5 Thermal proprieties of indoor environment

Our study is based on in situ measurement in summer period (auguste 2010). Measurement compaign was carried out in the living room. It aimes to study evolution of indoor environment temperature and evaluate buildings envelop performance. The collected climatic parameters were indoor dry air temperature and outdoor temperature. It acts on climatic data which defined the comfort zone.

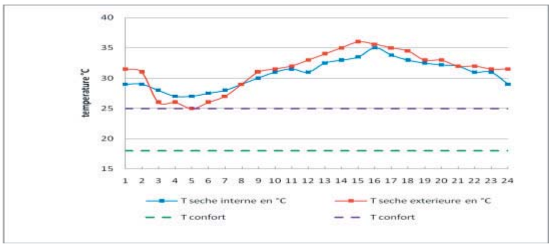


Fig.4. dry temperature average of indoor environment

According to the figure 4, the indoor dry temperature follows the movement of the curve of the external temperatures. During the morning the indoor temperature is more than the external one. Consequently, Indoor environment is situated in the overheating zone with a maximum of 35°C.

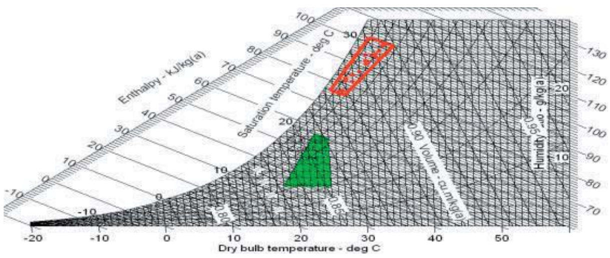


Fig.5. psychrometric diagram of indoor environment

These variations depend on four factors

- The amplitude of outside temperature (difference Tmax - Tmin),
- The bed thermal inertia of the room
- Solar gains
- The ventilation of the room, which can either restore the external amplitude

2.6 Thermal properties of soil

Before earth-cooling techniques can be discussed, the thermal properties of soil must be considered [9. Earth, especially wet earth, is both a good conductor and storer of heat [12]. The temperature at the earth's surface is the result of solar gain, radiant loss, and heat conduction to or from lower layers of the ground. Since air is heated mainly by its contact with the earth, the surface soil temperature is about the same as the air temperature with its large annual fluctuations. However, because of the large time lag of cooling the earth, the soil temperature fluctuates less and less as the soil depth increases.

The heat transfer mechanisms in soil are conduction, convection, and radiation. Conduction occurs throughout the soil, but the main flow of heat is through the solid and liquid constituents. Convection is usually negligible, with the exception of rapid water infiltration after heavy rainfall. Radiation is important only in very dry soils, with large pores, when the temperature is high. Therefore, the main parameters influencing the thermal behavior of the soil are thermal conductivity and heat capacity that are jointly expressed in terms of thermal diffusivity below [12]:

$$\propto = \frac{k}{\rho\varsigma}$$

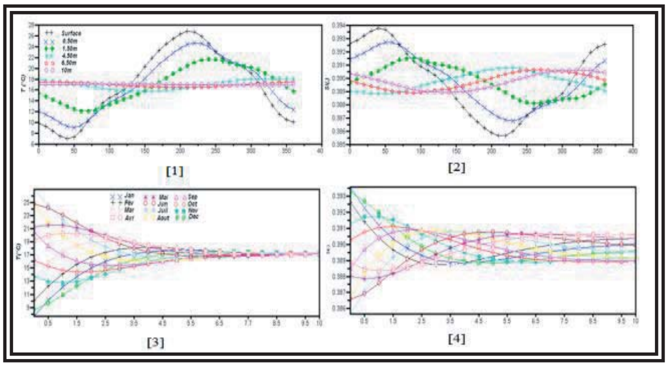
Where (k) is the thermal conductivity, (ρ) is the density, and (ς) is the specific heat of the soil.

According to geotechnical study, worked out by laboratory CTE GEOMICA, The soil type of Tizi Ouzou is heavy clay whil the diffusivity varies between 0.042 – 0.061 (m^2/day).

Tab.1. thermal proprieties of the soil

Nature	clay
Conductivity, W/(m K)	1.28 $w.m^{-1}.k^{-1}$
density	1500 $kg.m^{-3}$
Heat capacity	880 $j.kg^{-1}.K^{-1}$
ground covers	gras,
humidity	wet
Wind exposition	normal

The figure 6 presentes soil temperature evolution and moisture according to depth and time. Thes results have been experimented and simulated by laboratory on energetic researcher of the Mouloud Mammeri University, accoure that the underground have constant value à the depth of 3m which account about 17°C.



[1] température évolution according to depth

[2]evolution of soil moisture according to time and depth

[3] évolution of average monthly temperature according to depth

[4] évolution of average monthly soil moisture according to depth

Fig.6. soil temperature of Tizi Ouzou

2.7 Pipes prorprieties

For this study, we have used PVC pipes, caracteriesed by:

Tab.2. pipe proprieies

Nature	PVC
conductivity	0,6 $W.m^{-1}.K^{-1}$
Volumic Mass	790 $kg.m^{-3}$
Heat capacity	1520 $J.kg^{-1}.K^{-1}$
Pipe thikness(m)	0,06
internal Diameter di(m)	0,188
External Diameter (m)	0,2

3. Simulation

First stage: Control heat gains due to solar radiation and heat exchanger with external environment by applying external insulation on building envelope and recourse to seasonal solar protection of the roof. These parameters will be simulated with TRN SYS.

Second stage: Control exchanger's air flows by air soil heat exchanger. In this step, we try to identify the geometrical configuration determinate by the length of pipes, in order to obtain an indoor temperature at the exit of the pipe account for 21 °C, we obtaine 39,6 m. This value is calculated from a mathematical equation (excel table):

$$L = \frac{\rho . q_v \ . Cp . (T_{air} - T_{desired})}{\varphi \ per \ m \ linear}$$

ρ= density (kg/m3) (1.2) ;
qv = débit = 0.16m3/s
Cp=1004(J/Kg.K) mass capacity of dry air

$$\varphi \ \mathbf{flux}, \varphi = \frac{(T_{soil} - T_{air})}{R}$$

To regard thermal behaviour of the air inside pipes and identify performance, we use Scilab as a multi-fields platform of simulation to modelling dynamic systems. It is a convivial modular environment developed in a simple program language for MATLAB and which uses its metric solver.

The model is treated as a data. By present simulation, we wish to check that we will obtain at the exit of the pipe a temperature of 21°C according to the length of tube (39,6) equipped by one pipe or three pipes .

To regard thermal behaviour of the air inside pipes and identify performance, we use Scilab as a multi-fields platform of simulation to modelling dynamic systems. It is a convivial modular environment developed in a simple program language for MATLAB and which uses its metric solver. The model is treated as a data. By present simulation, we wish to check that we will obtain at the exit of the pipe a temperature of 21°C according to the length of tube (39,6) equipped by one pipe or three pipes .

4. Results

The envelope of the building is characterized by a bed inertia, we announce that the solar gains coming from the roof, the solar gains received by the south Western elevation during the day and the accumulation of the internal gains are the principal sources which seriously affects thermal environment by creating a discomfortable environment for user (the effect of the relative humidity).

Control the solar heat gains and heat exchanger throw the envelope by applying external insulation and seasonal solar protection contribute to reduce effects of external conditions, but the indoor environment is always in overheating zone. We have to control exchanger’s air flows by introducing air into building via air soil heat exchanger.

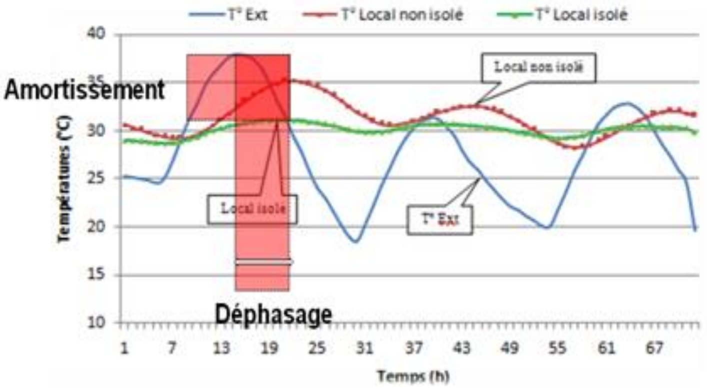


Fig.7. Temperature average before and after applying insulation

- If we consider the lenth of pipe at 39.6 m we abtain at the exite of instalation atemperature value at 24°C, which is far from the desired temperature.

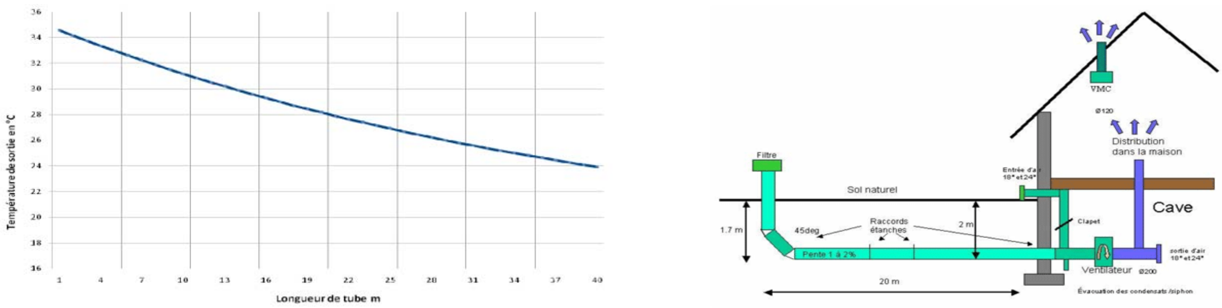


Fig.8. Temperature evolution inside one pipe

- If we take three pipes, lenght of every one is 39,6m we obtain a temperature at the exit at 21°C.

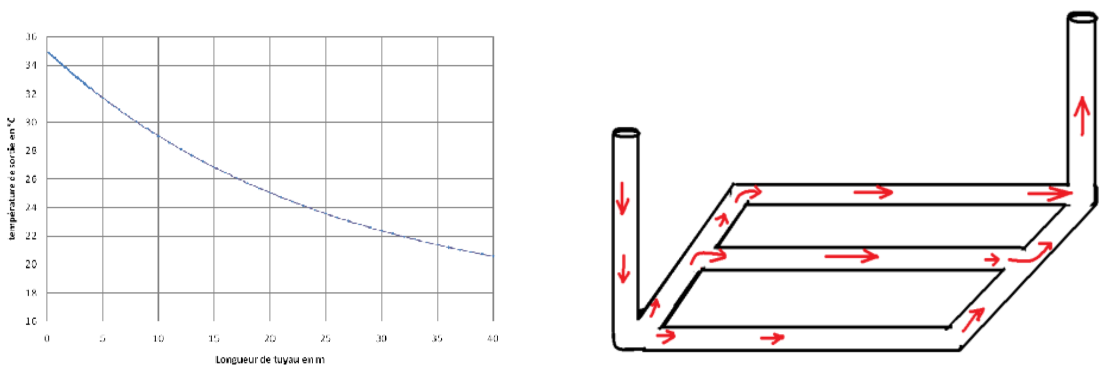


Fig.9. Temperature evolution inside 3 pipes

5. Discussion

The modelisation of earth to air heat exchanger is related to the length and number of pipes. The powerful solution is to take three pipes to reach goals of the study. If we take one pipe, the air speed is important. However, the air cannot take the necessary time to be cooled. In addition to that, the pressure losses are so important. Also, we propose to instal principal pipe (principal pipe) going until 3m of depth where the temperature of ground is approximately 17C. This principal pipe will be linked to 3 horizontal pipes of 40m length with a slower speed of air flow (to have time to cool and reach the desired temperature). At exit of these 3 pipes, they are again connected to a principal pipe. This one will be connected to building. It should be noted that the pressure losses for this kind of fitting are not significant which are directly related to pipe's diameter.

6. Conclusion

The present paper deals with the development of a new integrated method to calculate the contribution of the earth to air heat exchanger to reduce the cooling load of the buildings.
In a first time, we have try to presente parameters for modelisation the earth to air heat exchanger, but consider only the soil propriety is a big mistake. However, some measures must be considered on building enclosure: Control heat gains due to the external, the solar radiation through the windows, heat exchange through the opaque external walls (walls external and roof) or glazed. That may be possible by:

- increasing thermal mass (exterior insulation of roof, walls),
- avoid direct ventilation and predict solar protection to glazed surfaces, and roof
- Control heat gains due to equipments and user behavior by using a performing apparatuses and increase user control behavior
- Connected building with controlled mechanical ventilation with low energy loads.

One of the disadvantages relating to this system is pipe lengh which requires a larg area or larg yard considered as a saisonal sotrage. However, it will be possible to mantain this solution in urban statement only in section where building density is not important.

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THE LINKAGE OF ENVIRONMENTAL REQUIREMENTS WITH THE SELLING OF BUILDING PLOTS – AN EXAMPLE

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Summary

Today, cities are searching for ways to comply with national climate targets. City authorities are responsible for city planning and therefore defining the eco-efficiency of cities for decades to come. They need clear guidelines on how to reduce greenhouse gas emissions from the building stock in a particular area. Increasing the use of sustainably sourced wood in the construction could play a vital part in the transition towards eco-cities. In this paper an actual research project creates target values for cities regarding greenhouse gas emissions, primary energy and mass of renewable material for specific building plots. The proceedings and up-to-date results are shown in this paper. To achieve this, we studied life cycle assessments for different buildings. Wood as a building material is introduced for a minimal environmental footprint. The focus is set on linking the sale of building plots with the agreement to build primarily with wood. Target values for the buildings were developed in close cooperation with the city and are currently linked to tendering of the plots. The implementation of these values will be monitored in the near future.

Keywords: Sustainable real estate development; wood; carbon storage; timber structures; life cycle assessment

1. Introduction

Europe in general and especially Germany have defined climate protection goals to be reached in 2020 and thereafter. Their implementation requires involving all subareas, from industry, infrastructure to buildings and cities. Therefore cities and municipalities are searching for ways to comply with national climate targets. The so named “Eco-cities” seek to minimize their environmental footprint through, for example, the use of carbon neutral energy, more efficient city planning and by producing less waste.
The building sector has been identified as a major contributor to environmental pollution. The sector accounts for about 40% of the total energy consumption of the world [1], which causes a severe environmental impact. Moreover 40% of raw material consumption of the world comes from the building industry [2]. Optimization of environmental impact during a building life cycle is a significant aim in the context of sustainable development.

In the past discussions on climate change the building sector concentrated on energy efficiency, but now the focus has broadened to include sustainability of materials. Increased energy efficiency in the operational stage shifts the focus to primary energy consumption of production and the greenhouse gas emissions in the production stage. Further possibilities for increased CO2-reductions are always searched for. Wood as material which stores carbon temporarily is one way to increase the CO2-reductions further.
City authorities are responsible for city planning and therefore defining the eco efficiency of cities for decades to come. They are gatekeepers of building permissions, ensuring buildings meet environmental goals. Hence local authorities' guiding role in energy efficiency issues and "low carbon building" is growing, they need to advise on methods and tools for the design process. Increasing the use of sustainably sourced wood in building construction could play a vital part in the transition towards eco-cities. Therefore city planners need specific guidelines on how to reduce greenhouse gas emissions with the building stock in a particular area.

2. General issues on low carbon city planning

Sustainable city planning or planning of "Eco-cities", which are designed in consideration of environmental impacts, is seen as a step towards reaching the climate reduction targets. There is no predefined set of criteria to define a "Eco-city". But in any case environmental, economic and social needs should be satisfied. An ideal "Eco-city" has been described with the following requirements [3-5]:
- selfcontained economy, resources needed are found locally
- carbon-neutral energy production from renewable sources
- public transportation system with priority to walking, cycling and on public transportation
- maximize efficiency of water and energy consumption, creating a zero-waste system
- affordable housing for all socio-economic groups and improved job opportunities for disadvantaged groups
- support of local agriculture and produce
- promotion of voluntary simplicity in lifestyle choices, to decrease material consumption, and increase awareness of environmental and sustainability issues

These criteria represent a holistic look towards new targets for city planning. In present days cities are trying to achieve some of these requirements when designing new urban areas.
In this paper we present the development of a new quarter in Munich. Here issues of sustainable urban planning were considered by building a part of the site as "Eco-city" and therefore defining specific requirements for these buildings. To reach low carbon consumption the buildings must at least have energy standard KfW 70 and should be realised with only having energy provision by renewable sources and with predefined building materials for use. The quarter is connected to frequent public transport, some buildings are reserved for affordable housing.

3. Carbon footprint as an instrument for building with wood

3.1 Scope

Actual ongoing research on general life cycle analysis values for timber buildings in Germany and their implementation in city planning on an exemplary plot are presented.

The paper is based on the research project *development of a method to specify target values for CO2-equivalent and primary energy input* funded by the DBU - German federal Environmental Foundation. The projects aims at three objectives:

- Developing of environmental reference values for erection of buildings,
- support of the implementation of timber construction in urban development
- monitoring of the individual planning steps.

In this paper we show the proceedings and first results. The project started in summer 2014 with the creation of reference values for the agreements within the city regarding greenhouse gas emissions, primary energy and mass of renewable material for specific building plots.

We defined average and target values for the amount of renewable material and the maximum of permitted greenhouse gas emissions for building construction. To achieve this, life cycle assessments for buildings in different use categories needed to be studied. From selected realised timber buildings and buildings with mineral construction, reference values were generated. We left values for primary energy aside as the actual dataset in ökobaudat.2011 [6] shows huge differences in the indicator primary energy (renewable and non-renewable) for wooden products compared to actual EPDs for the same products.

With these values, the preliminary design stage can be influenced. Modern timber construction can serve as a vehicle for the implementation of resource efficiency and reduction of greenhouse gas emissions. But up to date no integrated procedure exists to implement these environmental criteria in the complete planning process.

We developed these target values in close cooperation with the city and currently are linking them with the tendering of the plots. The implementation of these values will be monitored in the near future. Planner will get advice on how to reach the agreed benchmarks and how to comply with building regulations (e.g. fire safety). Reference values need to be developed so that LCA calculations can be used for planning purpose and to highlight the influence of material choices in energy efficient buildings.

3.2 Case study

The city of Munich is currently planning a new residential quarter on a former military conversion site with 1800 units. The goal is to develop strongly needed affordable housing and at the same time to address issues of energy efficiency and environmental impact with innovative approaches. The development plan for the new quarter is shown in figure 1 and shows a wide variety of buildings.

g. 1 Masterplan for Prinz-Eugen-Park in Munich; red line indicates the part für “Eco-city”

The southern part of the quarter will be designed as an „Eco-City". In this part – outlined by the red line in figure 1 - around 500 flats are to be built. Framework for the „Eco-City" is innovative energy supply with renewable energies, buildings in plus-energy-standard and building with wood, a mobility concept and shared facilities. The „Eco-City" contains small terraced houses, free standing four story-buildings and 5-7 multistory residential houses.
The city administration wants to settle its pioneer role in building with wood and therefore looks for a way to minimize the environmental footprint of buildings. The city administration as owner of the plots wants to link the sale of building plots to the agreement on building with wood. Basic principle is the existing environmental criteria-guideline by the city of Munich [7], which sets minimum requirements to reduce resources, energy and CO2-emissions. To implement these specifications precise targets and goals need to be described. The implementation of timber buildings in an urban context of this size demands high standards in preliminary planning and all other building stages. For example the adaption of fire regulations in this context needs preliminary consent with planners and fire fighters.

3.3 Calculation of environmental reference values

In the first step we set up agreed criteria with the city of Munich, which could be used in procurement for selling the plots. We have chosen the indicator global warming potential as one of the most researched indicators in LCA calculations. Additionally the amounts of renewable material and carbon storage are used, as they can highlight the specific properties of timber buildings best. All criteria were assessed by the functional unit of one sqm of gross external area (GEA) of building. We examined more than 20 recently constructed buildings in order to generate robust data. All buildings were assessed with database ökobaudat.2011 and calculated without basement but including foundations. We have chosen calculations without basement to overcome the huge influence of basement on the results. All construction material and technical equipment was included in the bill of quantities. All buildings have a high performance in the operational energy consumption (around 50 kWh/m² or less). The buildings, which were assessed, have various construction methods, from massive timber buildings, timber frame construction, hybrid buildings to mineral buildings (brick, concrete with external thermal insulation composite system). Around two third of the buildings are wooden constructions. The size of the buildings varies between 176 m² up to 6.152 m². Most buildings are of residential use. Calculations were done with the LCA-tool Legep [8]. In this paper only results of the production stage according to EN15978 [9] are shown. The calculated buildings are shown in table 1.

Table 1: Analysed buildings

small residential buildings (number)	*Primary construction*	*Floor Area GEA (m²)*	*Number of floors*	*Year of erection*
1	mineral	215	2	2012
2	mineral	176	2	2008
3	mineral	176	2	2008
4	mineral	245	2	2011
5	timber frame	176	2	2008
6	timber frame	184	2	2011
7	timber frame	190	2	2011
8	timber frame	127	2	2011
9	timber frame	198	2	2011
10	CLT	379	2	2012

11	CLT	215	2	2012
12	CLT	176	2	2008

large residental buildings	*Primary construction*	*Floor Area GEA (m²)*	*Number of floors*	*Year of erection*
1	mineral	1394	6	2013
2	mineral	7016	4	2007
3	mineral	1898	4	2010
4	mineral	6152	3	2006
5	hybrid	1172	5	2013
6	hybrid	3735	5	2008
7	timber frame	1394	6	2013
8	timber frame	2717	4	2013
9	timber frame	6152	3	2006
10	CLT	1919	8	2011
11	CLT	3735	6	2008
12	CLT	1257	4	2011
13	CLT	698	4	2010

Results of the calculations are shown in figure 2 and 3 for global warming potential, and in figure 4 and 5 for renewable material.
Findings show that there are big differences between large and small buildings in all the calculated categories. Additionally differences in the results exist due to the different construction methods. Therefore assessment values were divided into two categories: large residential buildings and small residential buildings (terraced houses, detached houses). For actual implementation of the criteria the separation helps to promote specific construction methods.

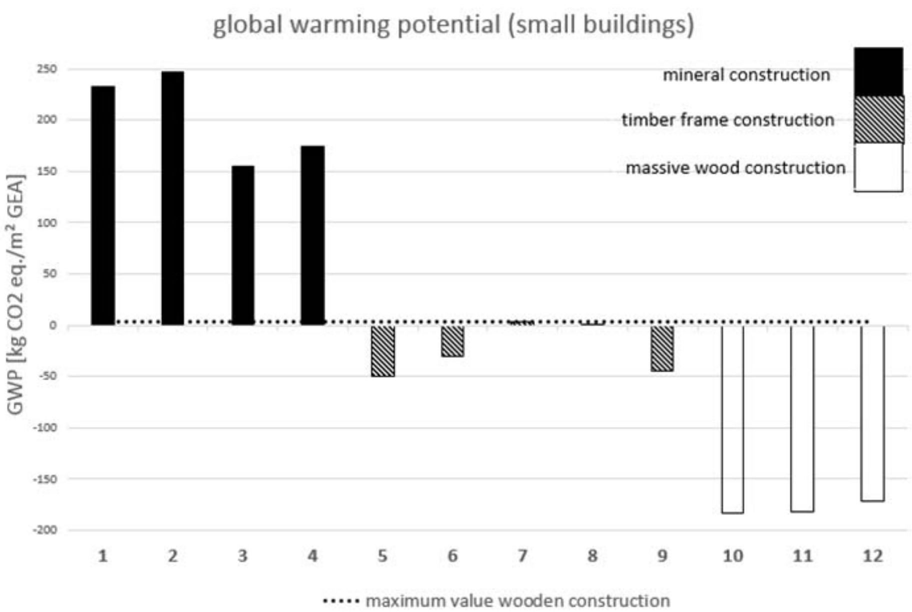

Fig. 2 global warming potential for small buildings in Germany with limit values / reference value per m² GEA.

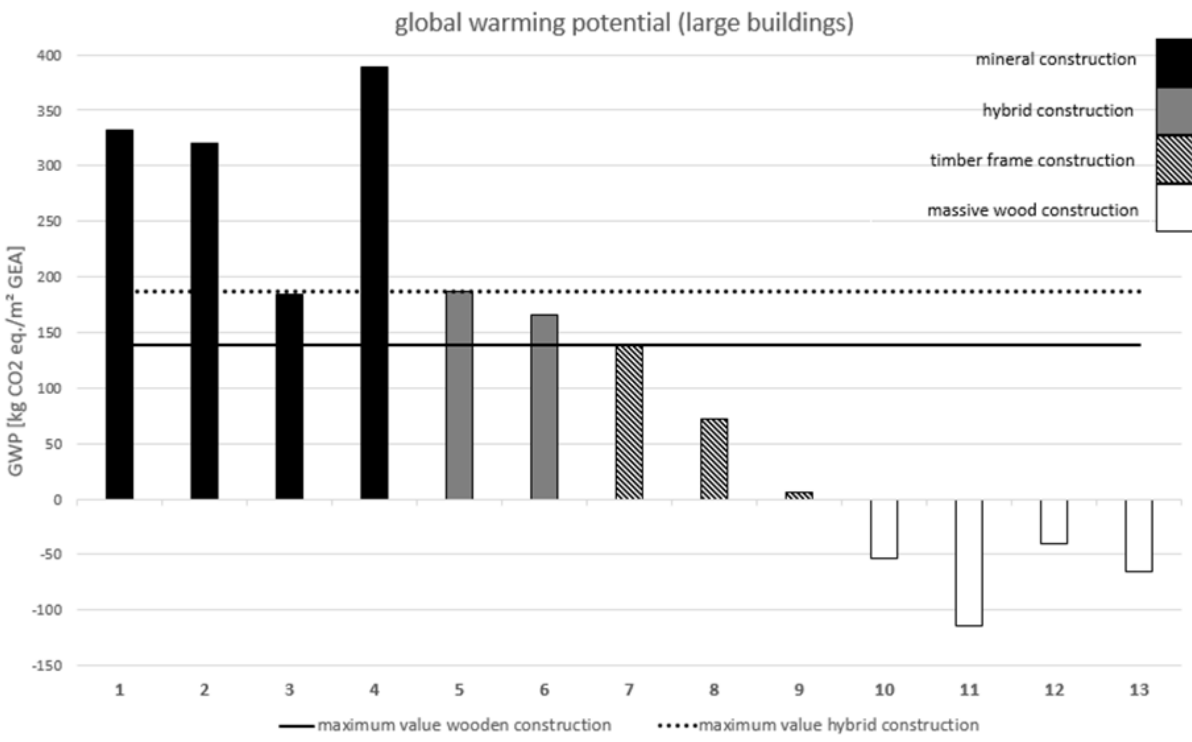

Fig. 3 global warming potential for large buildings in Germany with limit values / reference value per m² GEA.

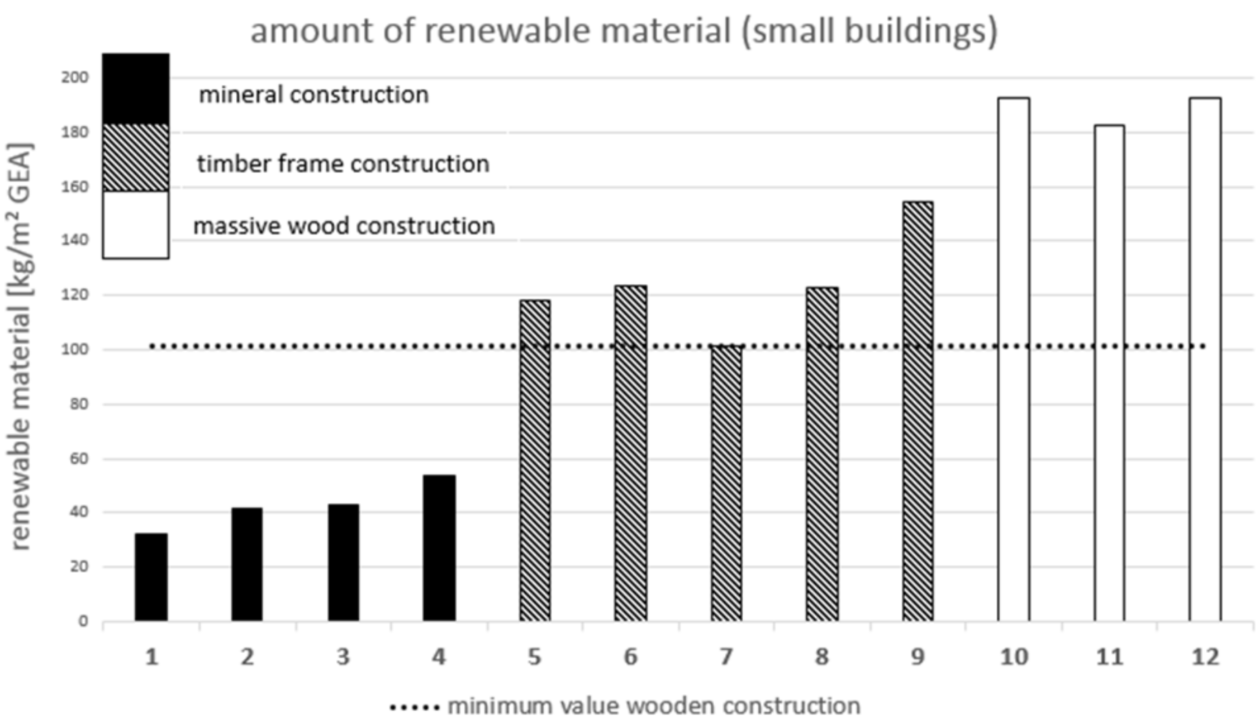

Fig. 4 amount of renewable material for small buildings in Germany with limit values / reference value per m² GEA

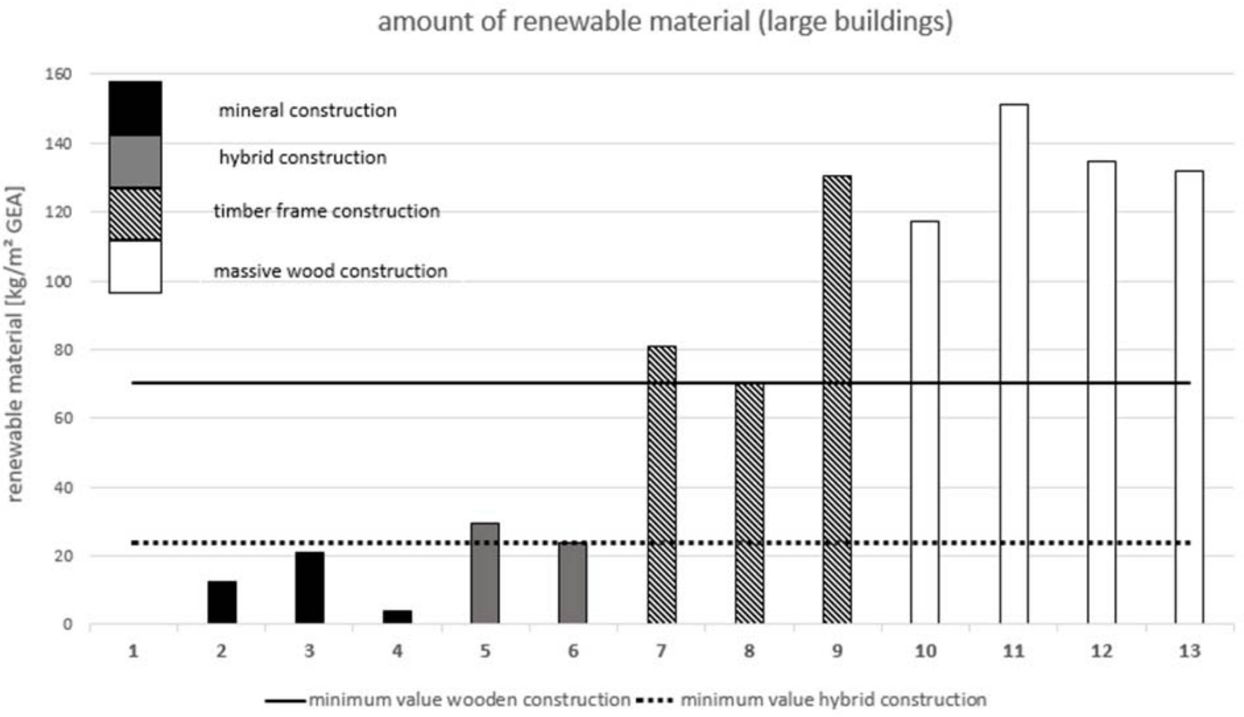

Fig. 5 amount of renewable material for large buildings in Germany with limit values / reference value per m² GEA

Differences occur due to a higher percentage of façade per m² for small buildings but also increased requirements for large residential buildings in terms of fire regulations, sound protection and primary structure. All these issues alter the material input significantly. To gain robust reference values we analysed the building values statistically and worked out a corridor with a minimum value, an average value and a maximum value.

3.4 How to proceed with these values in city planning

We calculated average values, maximum and minimum values across all buildings, as shown on the chosen indicator global warming potential and amount of renewable material in figures 2 to 5. Thereby individual characteristic values were identified for small and large buildings. The specific values for non-residential buildings can be merged with the values for large buildings as they show close similarity.

In LCA calculations we made a distinction between various construction methods (mineral construction, hybrid buildings, timber frame construction, massive wood construction). Variations of buildings with specifications in construction of load bearing walls, floors and roofs were calculated to determine the requested values and how they could be achieved. The graphic analysis show results for each building type and are subdivided into type of construction. Hereby the calculated average value correlates with the target value which should be achieved. The minimum respectively maximum values need to be reached as a minimum requirement.

We calculated the values which need to be reached as a minimum requirement by adding safety factors. The suggestion is to set the safety factor to be 10% of the values. The idea behind the safety factor is to equalise differences in design, actual state of the art in timber construction and other requirements. These values now represent amongst other things the basis for procurement of the building plot.

In cooperation with the city these values were discussed. To make the handling as simple as possible the city administration decided to only use the indicator amount of renewable material.

The numbers necessary for this calculation in planning stage can be generated by the planners without necessary skills in LCA. In the planning process (construction design and tendering) an exact bill of quantities of the used wooden material can be made. These exact calculations allow to apply for a "specific grant" to be introduced for that particular quarter.

As the city of Munich wants to promote timber buildings they have adapted the existing grant "CO2-bonus program" [10] - especially assigned to wooden construction - to this „Eco-City". To acquire this grant, the exact amount of wooden material in the building has to be proved. The introduced grant consists of a promotion of timber in primary construction with 0,70 € to 2,00 € per kg stored CO2. Calculation herby is made through exact bill of quantities and verified by bills of carpenters. An additional proof on sustainable forestry for the used wooden material is necessary. This is important as only sustainable sourced wood is positive on climate targets. The exact level of subsidy is calculated through an adjusted, programmed excel-sheet on the basis of the Munich CO2-bonus program.

The minimal requirements were defined by the city and then confirmed by city council. In that process some deductions to the "Eco-city concept" had to be made for political reasons. High energy performance required by city was scaled to the use of local district heating network and no additional demands (like plus energy standard). The environmental quality of the site was finally reduced to the use of renewable building material, mobility concept, shared facilities and possible limitation of living area only.

3.5 Implementation of environmental reference values in tendering of building plots

Using the decision of city council as a baseline we supported the city to work out the tendering document for selling the building plots. Two plots were given to urban housing societies with the requirement to builds with minimal amount of renewable material of 50 kg/m² living area. This correlates with building houses in hybrid construction with at least outer shell in timber frame construction and loadbearing structure in concrete. With this construction the fire safety regulations can be met through early introduction in planning process.

All the other plots are exclusively sold to joint building ventures and one plot to a cooperative building society. A competing procedure is installed. The procedure is structured through an application process, where the potential buyers have to submit a proposal with statements to assessment criteria. These assessment criteria are environmental issues (minimum amount of renewable building material fixed to 3 different levels, usage of rainwater), mobility concept, shared facilities in the building and roof terraces and possible limitation of living area to accepted standards [12]. The criteria will be assessed through a point range and the applicant with the highest score will get the site.

These plots will pass through the tendering process in spring-time 2016. After final decision the buyers will be obliged to discuss their proposals several times during planning process with an expert panel. This shall help to meet the set targets concerning the use and compliance with renewable material masses and to achieve an early integrated planning approach with respect to the structural framework and fire safety regulations in connection with building with wood. The aim is to prevent defective design.

For the future planners of the sites some support will be provided in form of calculation sheets for amount of renewable material (and temporal carbon storage), documentation with which combination of constructions the target values can be achieved, general achievement from consultation process with fire brigade and for the site applicable fire regulations and their influence on building with wood.

4. Discussion

With the findings of chapter 3 it is possible to draft reference values for different building types for the preliminary design stage of a construction project. Reference values also should help in the transition towards resource efficient Europe, as “clear environmental information” is requested in the “Roadmap for Resource Efficient Europe 2050” initiative. These abstract values and research findings need to be broken down into very practical level for planners. On exemplary buildings and their LCA calculations the set target values are now brought together with requirements on fire safety. A list of possible timber and timber-concrete constructions [13] which meet the necessary fire regulations is adjusted for the site. This is seen as an appliance for planners.

The amount of renewable material as an indicator for environmental city planning has to be discussed critically. On the one hand the linkage of building plots to only the amount of renewable material used leads into using as much timber as possible in the construction. In terms of carbon storage this construction is privileged but in terms of resource efficient use of material other material combinations might be better. For the future it needs to be resolved which way of doing or with combination is more sustainable.
Additionally there should be an addition requirement for energy efficiency in terms of use of renewable energy sources and energy efficient construction. Without the combination of the issues of energy efficiency in operation and energy efficient construction only mediocre benefits could be made out of the situation.

Focusing on LCA calculations it is important to show a holistic perspective of the results. In a next step all life cycle stages according to DIN EN 15978 will be evaluated. This means that beside module A also material impact in module B2-B4 (maintenance, repair, replacement in use stage), module C (end-of-life stage) and module D (potential benefits and loads) will get analysed. These holistic calculations then can show all material inherent differences of various constructions properly. The additional indicator carbon-storage is outside the set of commonly agreed LCA indicators and mainly of relevance for renewable materials.

5. Conclusion

The building sector has been identified as a major contributor to reduce greenhouse gas emissions in Europe. Due to the fact that buildings get more and more energy efficient in use stage of buildings, the carbon footprint of building material comes into focus. Here already in procurement of building plots target values for carbon emissions can be implemented. From environmental perspective wooden products have various advantages but should always be studied with material efficiency in mind. An approach to promote timber buildings can contribute to reach climate protection targets. At the same time it helps to foster building with wood in urban areas. All based on the requirement that the wood derives from sustainable forestry.
In the light of sustainable city planning the explained indicator could be a piece for achieving this. Energy and material choice from renewable sources must be looked at through the focus of resource efficiency and additional local economy. Truly sustainable “Eco-cities” still are rare, but introducing the ideas and achieving at least part of it is worthwhile.

6. Acknowledgements

This study was carried out with the research project *development of a method to specify target values for CO2-equivalent and primary energy input* funded by the DBU - German federal Environmental Foundation. The authors gratefully acknowledge the assistance of all concerned. Some of the LCA-data used was calculated by Holger König for the DBU-project [11].

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Thermal mass behaviour of concrete panels incorporating phase change materials

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Summary

Phase Change Materials (PCM) have been incorporated into a range of building envelope materials with varied success. This study investigates two different methods of combining concrete and phase change materials to form PCM/concrete composite panels. The first method involves adding microencapsulated paraffin to fresh concrete during the mixing process. The second method involves vacuum impregnating butyl stearate into lightweight aggregate which is then included in the concrete mix design. The primary aim of the study is to determine which method is the most effective way to improve the thermal mass characteristics of a concrete panel in the context of a thermal energy storage system for space heating in a building. The study observes the rate at which the panels absorb and emit heat, ie, the heat flux, and also how the heat flux changes throughout the depth of the panel. The panels are heated in a controlled environment provided by a specifically designed light box. Radiation is used as the heat transfer mechanism. Surface and internal temperatures of the panels are recorded during heating and cooling periods. The data recorded, together with the determined densities and thermal conductivities, are used to compare the thermal mass behaviour of each type of panel and to determine the influence that the method of incorporating a phase change material into a concrete panel has on the effectiveness of the PCM to improve the thermal mass characteristics of the concrete panel. The study highlighted the complexity of thermal behaviour of PCM/concrete composites. The panels containing PCM displayed significantly greater thermal storage capacity despite having reduced thermal conductivity and density. The study concluded that the panel containing lightweight aggregate/PCM composite is more effective at providing additional thermal storage particularly within the first 100mm of depth of an element of structure.

Keywords: Phase Change Materials (PCM), PCM/concrete, thermal mass, thermal diffusivity, thermal storage

1. Introduction

As the main consumer of material resources and energy, the construction industry has great potential to develop new efficient materials that reduce energy consumption in buildings. Using the mass of a building as a heat storage system can reduce the demand on the heating and/or cooling systems of the building. Concrete is a dense building material that combines a high specific heat capacity with a thermal conductivity that is appropriate for the diurnal heating and cooling cycle of buildings. The heat storage capacity of concrete can be enhanced by adding phase change materials (PCMs) which provide a high latent heat storage capacity. A thermal energy storage system can utilize sensible heat storage, latent heat storage or a combination of both. In sensible heat storage systems energy is stored in a material by increasing the temperature of the material. The capacity of a material to store energy depends on the amount of energy required to change the temperature of a unit amount of the material, ie the specific heat capacity of the material. The storage capacity of a sensible heat system is given by [1]:

$$Q = \int_{T_i}^{T_f} mC_p \, dT \qquad (1)$$

where:

Q = quantity of heat stored, (Joules).
T_f & T_i = final temperature and initial temperature respectively (^oC).
m = mass of heat storage material.
C_p = specific heat capacity of material (J/kgK).

A sensible heat storage system can be provided in a building by using the mass of the building as the storage unit. The ability of a material to store heat is referred to as its *Thermal Mass.*

Thermal mass = mass x specific heat capacity (2)

For a material to provide good thermal mass it requires three properties:

i. A high specific heat capacity, C_p (J/kgK).
ii. A high density, ρ (kg/m^3)
iii. An appropriate thermal conductivity, k, that suits the required storage period (W/mK)

Another relevant thermal property of a material is thermal diffusivity, α, which relates the ability of a material to conduct heat to the ability of a material to store heat.

$$\propto = \frac{k}{\rho C_p} \quad (m^2/s) \qquad (3)$$

Thermal diffusivity indicates the rate at which temperature changes occur in a material. The larger the value of thermal diffusivity the quicker the material will reach temperature equilibrium with its environment.

The thermal inertia of a material denoted 'I' is a measure of the responsiveness of a material to variations in temperature. Thermal Inertia can be calculated using the following equation [2]:

$$I = \sqrt{\rho \, C_p k} \quad (J/(m^2K\sqrt{s}\,) \qquad (4)$$

where ρ is the density, k is the thermal conductivity and C_p is the specific heat. A high thermal inertia describes materials that characterize high thermal mass. Referring to equation (3) for thermal diffusivity, α equation (4) can also be written as follows:

$$I = \frac{k}{\sqrt{\alpha}} \qquad (J/(m^2K\sqrt{s}) \qquad (5)$$

It can be noted from equation (5) that the higher the thermal diffusivity of a material the lower the thermal inertia. Hence for a building material to provide good thermal mass it requires an appropriate balance between thermal diffusivity and thermal inertia.

The latent heat capacity of a PCM is the heat energy absorbed when the PCM changes phase. The temperature of the PCM remains constant during phase change. The heat capacity of a PCM/concrete composite material is not constant as it varies in accordance with the amount of phase change that has occured. As a result the thermal inertia and thermal diffusivity of a PCM composite will also vary depending on the phase state of the PCM. For PCM composites the heat capacity is a combination of specific heat capacity and latent heat capacity. For this reason this paper will refer to the overall heat capacity of the PCM/concrete composites.

The selection of a phase change material for a given application requires consideration of the properties of the phase change materials. Depending on the application, PCMs should first be selected based on their melting temperature. For example materials that melt below 15^{o}C are used in air conditioning systems for cooling spaces while materials that melt above 90^{o}C are used for absorption refrigeration [3]. For a space heating application in a building, only PCMs with a melting temperature within the range of human comfort temperature (18-22^{o}C) can be deemed suitable [4].

For this study the primary requirements for the PCM are:

- Fusion temperature around the human comfort temperature 18^{o}C and 22^{o}C.
- Chemical compatibility with concrete, steel and timber (formwork).
- Low volume change during phase change.

Both paraffin and butyl stearate have successfully been combined with concrete in previous research. The three predominant methods that are used for incorporating PCMs into concrete are immersion, vacuum impregnation and encapsulation. The immersion technique was used by a number of previous researchers [5], [6] and [7]. However the time required for the absorption of the PCM and evidence of leakage while in use were highlighted as problematic issues.

The vacuum impregnation method involves firstly evacuating the air from porous aggregates using a vacuum pump. The porous aggregates are then soaked in a liquid PCM under vacuum. Finally the PCM soaked aggregate is added to the concrete mix. Zhang et al [8] studied the ability of different types of porous aggregate to absorb butyl stearate. For the vacuum impregnation method it was found that an immersion time of 30 minutes at a temperature of 30^o C above the melting temperature of the PCM optimises the absorption of PCM.

The most commonly used method for incorporating PCMs into concrete is micro-encapsulation, where small PCM particles (1μm to 1000μm) are encapsulated in a thin solid shell which is made from natural and synthetic polymers. These microcapsules can then be directly added to the concrete during the mixing process. This method provides a relatively large surface area of PCM throughout the concrete and hence it has the advantage of a high heat transfer rate per unit volume. Other advantages are that the capsules prevent leakage and resist volume change during phase change. However the microcapsules can affect the mechanical properties of concrete [9].

For this study two methods of incorporating the PCMs with concrete were selected. Firstly micro-encapsulated paraffin is added to fresh concrete during the mixing process. In the second method butyl stearate is vacuum impregnated into lightweight aggregate which is then included in the concrete mix design. This study will also investigate and compare the thermal behaviour of concrete panels that contain GGBS together with phase change materials that are incorporated using the methods noted above. This study aims to establish an optimum method of incorporating the phase change material into the structure and also an optimum depth of PCM to maximize the efficiency of the thermal storage behavior of the phase change material.

2. Methodology

The test groups of sample panels for the experimental design were selected as follows:

1. 4No. Control mix panels (2No. with 50% GGBS)
2. 4No. Concrete/microencapsulated PCM panels (2No. with 50% GGBS)
3. 4 No. Concrete + PCM lightweight aggregate panels (2No. with 50% GGBS

Each concrete panel is 200mm x 200mm x 200mm. In order to record the temperature within the panels during testing each panel has 3No. thermocouples cast into the concrete at equal depth intervals of 50mm, together with thermocouples located on the front and rear faces. After casting the concrete panels are cured for 28 days and dried out for a further 28 days.

In order to replicate heat energy transfer from the sun while controlling the amount of heat energy that each panel is exposed to and ensuring that the panels are exposed to equal amounts of energy, radiation was selected as the mechanism of heat transfer. A particular artificial light source (Follow 1200 pro lamp) was used with which it is possible to control the wavelength of the electromagnetic waves that are emitted. In order to exclude the environmental effects such as temperature variation in the test room, an insulated light box was designed and constructed as shown in Fig. 1.

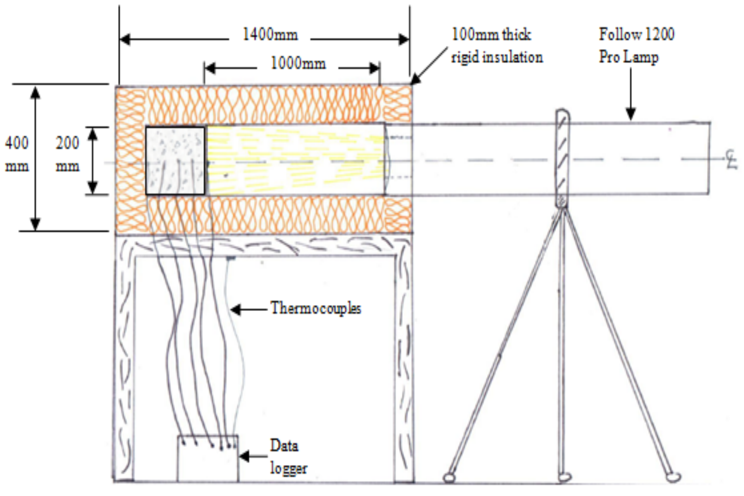

Fig.1 Schematic of the light box design

A microencapsulated PCM product called Micronal was used in the microencapsulated PCM panels. However the lightweight aggregate/PCM composite had to be manufactured. Preliminary tests were carried out on three types of lightweight aggregate to establish which type had the greatest absorption capacity. It was established that an expanded clay aggregate called LECA possessed the highest absorption capacity. The LWA/PCM composite was made by vacuuming the exact required quantity of butyl stearate (PCM) into the LECA.

The exact latent heat capacity of the PCMs was determined using Differential Scanning Calorimetry. These tests enabled the amount of latent heat capacity added to the panels to be accurately determined.

The conductivity of each of the panels was measured using an adjusted hot plate apparatus. The concrete panels were heated in the hot plate rig for 3- 4 days. When theconcrete panels reached steady state the heat flux, q, (W/m^2) exiting the front face of the concrete panel was measured using a heat flux pad. The heat flux measurement is given in W/m^2 which is equivalent to J/sm^2, ie q/At. The depth of the samples is known and hence the conductivity can be calculated from:

$$k = \frac{q}{At} \cdot \frac{d}{(T_h - T_c)} \quad \text{(W/mK)} \tag{6}$$

In order to observe and record the thermal storage behaviour of the panels, light box tests wer carried out in which each panel was placed in the light box, one at a time and heated by the lamp fc 12 hours. The panel was then allowed to cool while remaining in the light box. The temperature c the front and rear surfaces and at equal intervals within the concrete panel was recorded during th heating and cooling periods.

3. Results

3.1 The effect of PCMs on the properties of concrete

During the manufacture of the panels containing the LWA/PCM composite particles, the ‘stickiness’ of the fresh concrete suggested that some of the PCM leaked. It is likely that the heat of hydration causes the PCM to melt and as the LWA/PCM particles are not yet sealed by the hardened cement matrix the PCM can leak into the cement matrix. The leaked PCM may inhibit the migration of water and hence interfere with the hydration process and adversely affect strength development. Evidence of leakage of the butyl stearate was observed on the surface of the panels after they set (see Fig. 2).

Fig. 2. Leakage of PCM from the lightweight aggregate carrier

The addition of both the microencapsulated PCM and the LWA/PCM composite had an adverse effect on the strength of the concrete panels. Both types of PCM panels only achieved strengths in the order of 25MPa after 28 days (fig.3). The exact reason for the loss of strength requires further investigation. Notwithstanding this the strengths achieved are still suitable for some structural applications, such as non-loadbearing wall panels, low rise construction/domestic construction.

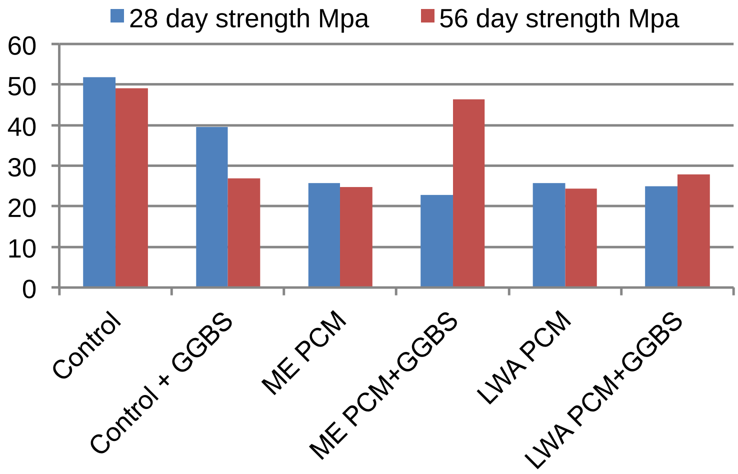

Fig. 3 Concrete strengths achieved

The thermal conductivity of each panel is a critical parameter as it directly influences the heat flu through the samples. The addition of both types of PCM resulted in a reduction in thermal conductiv ty of the concrete. The lower conductivity of the PCM panels resulted in reduced thermal diffusivit which in turn reduced the effectiveness of the PCM as depth increased as the heat took longer t reach the PCM.

The density of both types of PCM/concrete composites was lower than the control concrete due to the lower density of the PCM relative to the density of cement paste. The conductivity and density of the materials influence the thermal behavior however the effect that they have varies depending more on the ratio of conductivity to density of the material.

3.2 Heating behaviour

Eq. (1) can be rearranged to give:

$$C_p = \frac{\Delta \mathrm{Q}}{m \Delta T} \quad \text{(J/kgK)} \tag{6}$$

However for a PCM/concrete composite material the heat capacity varies during the phase transitio therefore as proposed by [11], eq. (6) must be modified to include the temperature gradient over tim

$$C_p = \frac{\mathrm{A.q}}{m\frac{dT}{dt}} \quad \text{(J/kgK).} \tag{7}$$

where ‘A’ is the area of the sample (m^2), q is the heat energy supplied to the sample (W/m^2), m is the mass (kg), dT/dt = increase in sample temperature in a given time step ($^oC/s$).

In the light box tests carried out as part of this research each of the panels was exposed to equal amounts of heat energy from the lamp over an equal time period of 12 hours hence the 'q' value is the same for each panel. Also the area exposed to the light is the same for each panel at $0.2m^2$. Hence the overall thermal storage capacity of the panels can be compared by evaluating the $m\frac{dT}{dt}$ value for each panel.

As noted previously the heat flux ie rate of heat transfer through the material, will vary throughout the depth of the material as the PCM changes phase. As a result the heat flux transferred to the surface of the sample is overestimated with respect to the internal temperature gradient over time which leads to an overestimate of the overall thermal storage capacity. To overcome this issue the applied heat flux 'q' is left in the equation as a constant and only the data from the three internal thermocouples at 50mm, 100mm and 150mm are considered.

The temperature data for each panel was analysed and the time taken for each 1^oC increase in temperature throughout the 12 hour period was determined, ie $\frac{dT}{dt}$ over time. Each $\frac{dT}{dt}$ value is then multiplied by the mass of the relevant panel and the reciprocal of the result is calculated, ie $1/m\frac{dT}{dt}$. This value is then plotted against time to observe how it varies over the 12 hour heating period. The higher the value of $1/m\frac{dT}{dt}$ the higher the thermal storage capacity. The overall area under the resulting curves is indicative of the overall thermal capacity and a comparison of the thermal storage capacity of the panels was made.

Fig. 4 shows a plot of the relative overall thermal storage, as recorded at 50mm depth. It is clear that the panels containing PCM provide greater thermal storage capacity. As confirmed by computing the area under each of the curves the lightweight aggregate panels provide the highest overall thermal capacity at a depth of 50mm.

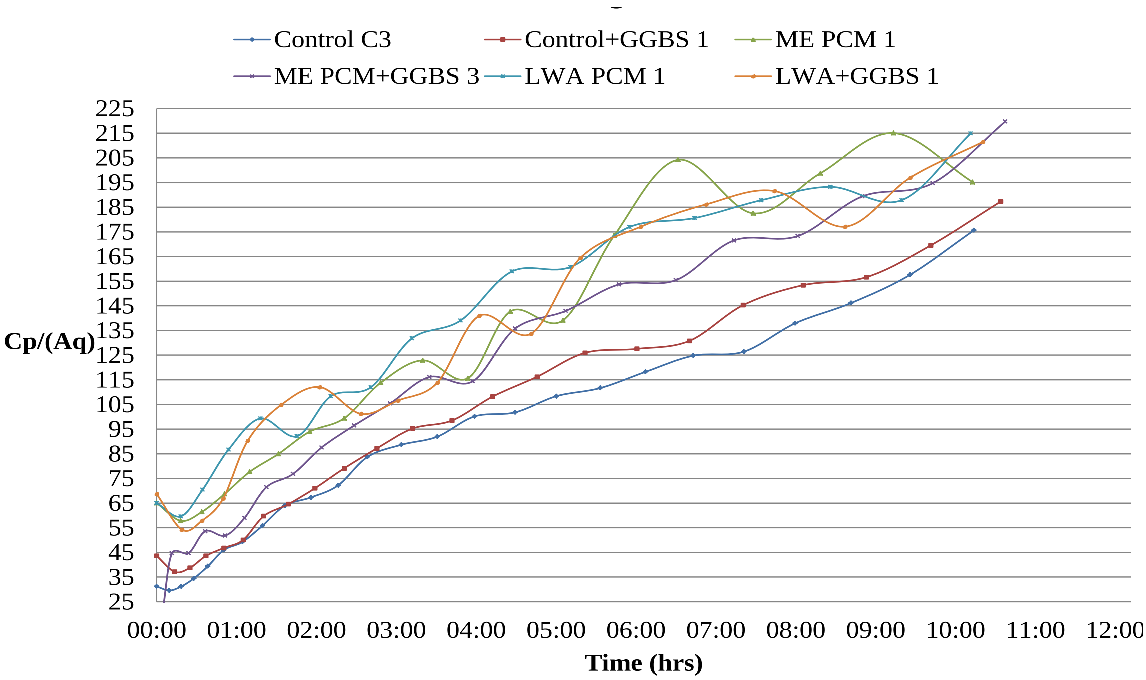

Fig.4 Curves showing relative overall thermal capacity at 50mm

The percentage of additional thermal storage and thermal mass provided by the PCM panels was determined by calculating the area under each curve and setting the value for the control curve at

100%. The results are shown in table 1. It is noted that the LWA PCM panel and the LWA PCM+GGBS panel provide the greatest increase in thermal storage of 61.7% and 59.4% respectively. The panel with microencapsulated PCM (ME PCM) panel and ME PCM+GGBS panel also provide a significant increase in thermal storage of 57.5% and 54.6% respectively.

Table 1. Additional thermal storage provided by PCM panels at 50mm, 100mm and 150mm depth

Panel Type	% Overall thermal storage relative to control panel at:		
	50mm	100mm	150mm
Control	100.0	100.0	100.0
Control +GGBS	129.9	112.0	105.0
ME PCM	157.5	147.0	152.0
ME PCM + GGBS	154.6	136.8	125.8
LWA PCM	161.7	143.0	147.0
LWA PCM+GGBS	159.4	147.0	154.0

It can be noted that the overall thermal storage of the PCM panels reduces relative to the control panel. Part of the reason for this is that the overall thermal storage for the control panel increases. However another factor that contributes to this behaviour is that the diffusivity of the control panels is higher than the PCM panels and the LWA panels have the lowest diffusivity as shown in fig. 6. This means that the heat is taking longer to reach 100mm in the LWA PCM panels, so over the 12 hours the overall heat reaching 100mm depth in the LWA PCM panels is less than that in the control panel and also the ME PCM panels. Hence the PCM becomes less effective with increasing depth. These panels were subjected to a high level of heat energy for 12 hours. In a real application, a concrete floor or wall would not be exposed to such high levels of heat. The level of exposure depends on both local climate and position of the concrete element within the building, ie exposure to daylight. So the effective depth of the PCM will depend on the proposed location of the composite material. In applications where the heat energy is reaching up to a depth of 100mm into the composite PCM material the LWA PCM panels provide a greater thermal storage capacity.

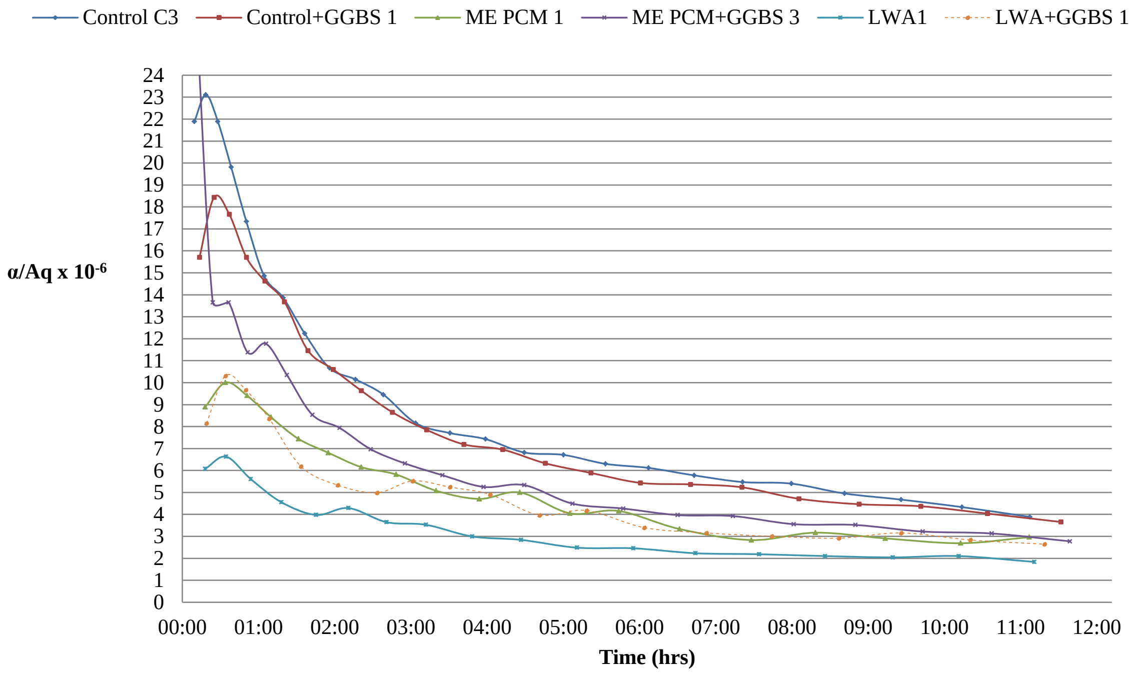

Fig. 6. Relative thermal diffusivity recorded at 50m

3.3 Cooling behaviour

After the 12 hour heating period the Follow Pro 1200 lamp was switched off and the panels remained in the light box for a further 12 hours to cool down naturally while the temperature data was recorded. The panels did not cool down sufficiently within this time period to induce a solidification phase change of the PCM within the panels, however some observations and comparisons can be made regarding the rate of cooling of the front surface of the panels.

A study of the data recorded showed that there was no notable difference between the cooling behaviour of the panels containing GGBS and the panels without GGBS.

An unexpected observation from the natural cooling data is that the front face of the ME PCM panel cooled at a higher rate than the control panel despite having a lower conductivity and lower density. However calculations showed that the ME PCM material has a lower overall thermal capacity C_p than the control panel outside of the phase change period. As there was no phase change taking place during this cooling period it can be assumed that the C_p value for the ME PCM panel is lower than C_p for the control and this is leading to a higher thermal diffusivity in the ME PCM panel facilitating the release of heat from the front of the panel.

It is also observed that the rate of decrease in temperature is similar for the control panel and the LWA PCM panel with the LWA PCM panel showing a slightly higher rate of heat loss at the surface. Calculation showed that outside of the phase change period the control panel and the LWA PCM panel have a similar heat storage capacity. The higher conductivity and density of the control panel is contributing to the slightly higher thermal inertia of the control panel.

4. Conclusion

Based on the results of the analysis presented in this paper the following conclusions can be made:

- At a depth of 50mm the LWA PCM and LWA PCM+GGBS panels provide the greatest increase in thermal storage capacity over and above the control panel.
- The overall thermal storage of the PCM panels reduces relative to the control panel as depth increases due to the fact that the diffusivity of the control panels is higher than the PCM panels. Hence the heat will take longer to reach a depth of 100mm in the LWA PCM and ME PCM panels. As a result the PCM becomes less effective with increasing depth.
- As depth increases the level of thermal storage provided by the ME PCM panel approaches the storage provided by the LWA/PCM panel and at a depth of 100mm the storage provided by the ME PCM panel was slightly greater than the LWA PCM panel. This means that for a 100mm thick wall panel or floor slab, the incorporation of a LWA/PCM composite is a more effective and efficient means of achieving a significant increase in the thermal energy stored.
- As thermal diffusivity is the parameter that is hindering the effectiveness of the LWA/PCM composite, improving the conductivity of the LWA PCM panels would further enhance the thermal performance of the material.
- The overall thermal storage of a panel will increase as the amount of heat energy transferred to the panel increases. In a real application where a PCM/concrete composite ma-

terial is used in a building to store thermal energy, the effective depth of the PCM will depend on the local climate at the proposed location of the building.

- The study of the data collected during the natural cooling of the panels within the light box highlighted a critical issue with the use of PCM/concrete composites in buildings, which is that the indoor temperature must fluctuate above the melting temperature and below the freezing temperature of the PCM within a 24 hour period. If this range of temperature fluctuation does not occur then the PCM will not discharge latent heat energy and will not have the capacity to absorb more heat the following day. The fluctuation in the indoor temperature depends on both the local climate and the level of insulation in a building. Modern buildings tend to be highly insulated to prevent loss of heat energy however high levels of insulation may hinder the performance of a PCM thermal energy storage element within a building.

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[1] http://www.project-impress.eu

Timber Building Details for a Leaner Design Process

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Summary

The concept of lean construction has been defined as an application of lean thinking in the design and construction process, aiming to create value for the customer and reduce waste. Building with timber is complex and waste in the planning process caused by redesign is not uncommon. This paper explores the feasibility to optimize this work with pre-designed details.

The study bases on four recent built cases. Selected structures and joint details as built are compared to available material in six European collections of pre-designed timber building details. The discussion evaluates the applicability in practice and whether the buildings could have been designed using ready-made material. The results show a large variation with some built projects matching well with national collections and others corresponding poorly with any of the presented structures or details in evaluated collections.

The conclusion is that a vast selection of pre-designed details exists. However, they are not yet used. Details as built are often the result of a collaborative development process between project partners and based on earlier experiences. From the viewpoint of European wide procurement and the competitiveness of timber building the findings are problematic. Clients are forced to accept system solutions and unable to receive comparable offers. The promotion of mass-customized timber building production would require more established common solutions.

Research leading to these results is part of the transnational WoodWisdom-Net Research Programme, project *leanWOOD*, Innovative lean processes and cooperation models for planning, production and maintenance of urban timber buildings.

Keywords: Details, leanWOOD, planning process, timber-building

1. Introduction

Lean culture is gaining ground in the construction industry. The concept of *lean construction* has been defined as an application of lean thinking in the design and construction process, aiming to create value for the customer and reduce waste of the production process. [1], [2] One tool to optimize processes is an increased use of standardized components. [3], [4], [5]

Building with timber is complex and often requires extensive efforts in design. Little research can be found specifically on timber construction processes. However, research identifies the design process as one challenge for leaner building production on a general level. Sources of waste in this process include e.g. excessive detail work and redesign. [4], [6]

This study is part of project *Innovative lean processes and cooperation models for planning, production and maintenance of urban timber buildings* (leanWOOD), 2014-2017, aiming to evaluate the applicability of lean culture to the timber building production process and especially the design phase. [7] This paper explores the feasibility of utilizing pre-designed details as standard components in the timber building design process. The study bases on four recent case projects and evaluates whether they could have been designed and built using available pre-designed material.

2. Methodology

Several European collections of pre-designed timber building details are published. Collections used in this study include the Austrian *Baubook* and *Dataholz*, the Finnish *RunkoPES 2.0*, the French *Catalogue Construction Bois* (CCB), the Swiss *Lignum Bauteilkatalog Schallschutz* (LBS), and *German Erarbeitung weiterführender Konstruktionsregeln/-details für mehrgeschossige Gebäude in Holzbauweise der Gebäudeklasse 4* (G4). [8], [9], [10], [11], [12], [13] The background and contents of these collections have been compared earlier by Cronhjort [14] and were selected based on the amount and variety of material available online, the representativeness of different European regulatory background, and the use or awareness of them among leanWOOD-project partners and countries. They illustrate national solutions of discussed cases.

Studied cases were designed, built or commissioned by partners in project leanWOOD. They represent different timber building solutions and typologies, correct craftsmanship with respect to current norms and proper structural protection of timber. The external wall and intermediate floor structures are compared to available solutions in all discussed collections. Joints between the external wall and roof, intermediate floor and foundation are compared to national versions. The Swiss case is additionally assessed against the Austrian Baubook. The discussion summarizes the findings and development of compared material.

3. Research Material

In buildings, the main structures typically follow established conventions and regulations for e.g. thermal insulation capacity and design for fire safety. Joints are more prone to variation and change during a design and building process. In increasingly energy efficient building, challenges occur especially regarding the air-tightness of details. Other issues include e.g. the general strategy of elementation. To examine and compare best practice with solutions offered by the selected collections these issues are the focal point of this study.

3.1 Cases

Selected case objects include an apartment house in Finland, two office buildings in France and Germany, and a multi-storey housing complex in Switzerland. They were designed, built or commissioned by leanWOOD project partners and finalized before commencing this study. Hence the applicability of discussed collections of pre-designed details to the production of timber buildings can be evaluated without affecting the process. Cases are presented in Table 1.

Table 1: Case projects discussed in this study. Data according to FCBA, lattkearchitekten, Rakennusliike Reponen Oy and Uffer AG.

Project	Case A Apartment house	Case B Office building	Case C Office building	Case D Apartment houses
Country	Finland	France	Germany	Switzerland
Gross floor area	11800 m^2	-	967m^2	2 621 m^2
Floor height	3 200 mm, typical storey	-	Ground floor height 2 946 mm	2 880 mm, typical storey
Storeys	7	5	2	4
Capacity	186 apartments	10600 m² (400 m² office space, 6600 m² labor space)	843m^2 rentable net floor area	4 apartment houses, 28 apartments, 1 970 m^2
Load bearing frame	Timber beams	Timber frame and Cross Laminated Timber	Cross Laminated Timber	Timber frame; timber concrete; box elements
Year of building	2014-2015	2013-2014	2013	2013-2014

3.2 Details and Structures Compared

This chapter presents the comparison of structures and joints as built to available material in discussed collections of pre-designed solutions for timber building. The external wall and intermediate floor solutions are compared to all collections and the joints to national collections only. One exception is the Swiss case which is additionally compared to the Austrian Baubook.

3.2.1 Case A – Apartment House, Finland

The Finnish case is a multi-storey apartment house built of pre-fabricated flat elements with a load-bearing timber frame-structure. It is compared to benchmark structures of the Finnish reference collection *RunkoPES 2.0*, specifically developed to support the development of such projects.

The external wall structure as built is presented in Table 2. The *RunkoPES 2.0* includes one close match: external wall structure US804KR designed for buildings up to 8 storeys. Exceptions include a thinner layer of thermal insulation and a stiffening layer of plywood as compared to the structure as built. Available CAD-objects can be modified and a structure corresponding to as built created.

The closest match to the intermediate floor as built is VP802BRL, with identical layers but some differences in structural thicknesses.

Table 2: Structural layers of the external wall structure in case A.
REI 60, 0.12 W/m^{2}K, R_W+C_{tr} 45 dB.

Thickness	Layer
28 mm	internal cladding (13 + 15 mm gypsum board)
0.2 mm	vapor barrier
270 mm	mineral-based thermal insulation
9 mm	wind barrier, gypsum board
50 mm	wind barrier, mineral-based thermal insulation
44 mm	air gap
28 mm	cladding
429.2 mm	total structural thickness

Compared joint details include the connection between 1) external wall and roof, 2) external wall and intermediate floor, and 3) the external wall and foundations. The closest match to the roof joint as built is DY402ER with the most resembling geometry but a need for modification. A joint similar to the as built solution between the external wall and slab cannot be found in *RunkoPES 2.0*. The built detail is simpler than the closest match, DV403KR. The foundation detail as built is different from the examples in *RunkoPES 2.0.* Main differences include the height of the ground floor slab as compared to adjoining structures, and the amount of external wall overhang. The built joint is more complicated than the pre-designed detail.

The external wall and intermediate floors as built were also compared to pre-designed details of *Baubook, Dataholz, CCB, LBS* and *G4*. No exact match could be found for the wall, however, structure type 6 in CCB and type AW2 in the German collection require only small changes. *Dataholz* contains several timber-framed options none of which has an additional layer of thermal insulation on the outside. No CAD-objects are available and modification must be done at the drawing board.

A close match to the built intermediate floor is found in *Dataholz* requiring only minor modification. Type TD1 in the German collection is fairly similar including one additional layer of mineral-based thermal insulation between the concrete floor and load-bearing structure. No corresponding solution is found in the Swiss *LBS*, French *CCB* or the *Baubook*. Identified differences include, in addition to dimensions, structural layers and the amount of gypsum boards.

3.2.2 Case B – Office Building, France

The French case is a multi-storey office building built of pre-fabricated 10m x 3.50m timber frame - elements with a load bearing timber beam-structure and intermediate floors in CLT. The external wall structure is compared to benchmark structures of the French reference collection *CCB*. The sizing of the structural elements is not taken into consideration in this comparison since the details available only deal with performances of the building envelope. External wall structure ME05 is the closest match to the built wall. The only difference is a thinner layer of thermal insulation. However, available CAD-objects can be modified and a structure corresponding to the built case created. The structure as built is presented in Table 3. Intermediate structure PI04 is the only floor available on the *CCB* with a structure in CLT and it is a very close match to the built floor. The main difference is the type and thickness of the layer used between the CLT and the concrete slab.

Table 3: Structural layers of the external wall structure in case B.

Thickness	Layer
36 mm	internal cladding on steel studs (18 + 18 mm gypsum board)
50 mm	mineral-based thermal insulation (lambda-value 0.035 W/m.K)
0.2 mm	vapor barrier
200 mm	mineral-based thermal insulation (lambda-value 0.035 W/m.K)
12 mm	sheathing board, OSB-panel
0.2mm	rain barrier
20 mm	air gap
21 mm	cladding
429.2 mm	total structural thickness

The joint between the external wall and the roof terrace in case B is closest to detail TT01-03 of the *CCB* with rafters on a tail trimmer. However, the external wall used in the detail does not match the one of case B. Detail TT01-03 is not replicated for the different types of external walls. Overall the joints used in case B are quite close to the pre-designed details available on *CCB* but there are no complete matches. However, the provided CAD-objects can be modified.

Among other collections, the external wall AW2 of the German G4 is the closest match but missing the additional insulation layer on the inside. Dataholz type awrhhi02a is also fairly similar but with one additional layer of particle board and differences in dimensions. RunkoPES 2.0 includes several close matches with main differences being the thickness of the single layers. A separate rain barrier on top of an OSB-board is not used on the outside but external weather protective gypsum board. In the Baubook, version AWI 01 a, is the closest match. However, several modifications are required to obtain a corresponding wall structure. Concerning the intermediate floor, type TD2 of collection *G4* is the closest match to the as built floor with a thicker acoustic layer. Several close matches can also be found in the *LBS*, e.g. A.3.01-02a-00-000a-00-110a-aa with the only difference being the thickness of single layers. *Dataholz* type gdmnxn02 is also close, with one additional material layer and differences in dimensions. A similar or even close match of intermediate floor cannot be found in either *RunkoPES 2.0* or the *Baubook*.

3.2.3 Case C – Office Building, Germany

The German case is an office building constructed using prefabricated building elements of Cross Laminated Timber (CLT). The construction fulfills the requirements for fire class “Gebäudeklasse 3”. Due to the availability of material and contents, selected case details are compared to the German G4, applicable to buildings of more demanding fire safety-requirements (Gebäudeklasse 4).

Table 4 lists the structural layers of the external wall as built. The solution resembles the suggested wall elements of the CLT-manufacturer [15] and a similar solution is available also in *G4*; type AW4. However, the layers of type AW 4 fulfill fire safety-requirements for REI 60, which was not necessary in the two-storey high office building. Due to lower fire safety-requirements the CLT structure is exposed and the surface treated with a silicate glaze.

Table 4: Structural layers of the external wall structure in case C.

Thickness	Layer
125 mm	massive timber (Cross Laminated Timber, CLT)
180 mm	timber-based soft thermal insulation
20 mm	timber-based hard thermal insulation
20-50 mm	air gap
24 mm	cladding
369-399 mm	total structural thickness

Similar joints as built, i.e. load bearing-connection and screws, are found. For example, the connection between external wall and the foundation is almost identical. However, the suggested roof structure in the collection does not match the solution as built. No exact match to the built slab is found but type TD3 comes close.

Structures close to the built solutions are found also in other collections. *Dataholz* type awmoho02 is fairly similar to the external wall as built, with two additional layers and different dimensions. External wall type US401KM *RunkoPES 2.0* designed for apartment houses of maximum four storeys is fairly similar with an additional gypsum board on the inside but lacking the additional thermal insulation layer on the outside. CCB contains only one external wall with CLT as load-bearing frame: type 9. The structure is similar to the benchmark except for the additional external thermal insulation layer but an assembly space and gypsum board on the inside. No close version is found in the Swiss *LBS* or *Baubook* collections.

The closest match to the intermediate floor is found in the Swiss *LBS*; A.3.03-02a-00-00a-40-112a-aa. *Dataholz* type gdmnxn02 has one additional layer of timber-based board and different dimensions. *Baubook* versions GDh01a and b differ regarding the amounts and dimensions of layers, and load-bearing structure, as they are designed for “Brettstapel”, not CLT. The Finnish *RunkoPES 2.0* includes three slab structures using CLT and *CCB* one. However, none of these allows for visible CLT due to the design for more demanding fire classes.

3.2.4 Case D – Apartment Houses, Switzerland

The Swiss case is a multi-storey housing complex of four buildings constructed using timber-frame in exterior walls. A hybrid construction of timber and concrete is used for the slabs and the flat roof was built using box-elements. The structures are compared to both the *Lignum Bauteilkatalog Schallschutz (LBS)* and the Austrian *Baubook* as the *LBS* only contains intermediate floor structures.

The external wall is compared to the *Baubook*. Structural layers are listed in Table 5. The wall is built with a 240 mm DUO-nsi Fi –beam (Note: Double beam-not visible-spruce) This option is not provided by the *Baubook*. However, the exemplary structure and inhomogeneous layers can be modified by deleting or changing dimensions, and comparing the chosen product for thermal insulation with other materials and see all their specified characteristics. It is not possible to modify other layers or change materials. Hence the external wall structure as built could not be composed. The slab and roof construction of the built project were not possible to recompose.

As the case object was finalized before realeasing the new Swiss fire-regulations in 2015, the only publication available at the time of planning and construction was LBS. The intermediate floor structure of case D is compared to this collection, which contains slab stuctures only. Structural layers of the slab as built are listed in Table 6.The process of identifying a corresponding solution starts with the sound insulation capacity and structural type. The next step requires the selection of a producer. However, the following steps do not allow for e.g. combining a particular producer with the option of using concrete instead of a loose filling. Hence it was not possible to find or modify any of the details to correspond to the as built detail.

Table 5: Structural layers of the external wall structure in case D.

Thickness	Layer
15 mm	gypsum board
40 mm	installation gap
3 mm	felt stripes
25 mm	OSB-board, air-tight
240 mm	mineral-based thermal insulation between DUO nsi FI beams
15 mm	wind barrier, hard thermal insulation
	wind barrier paper
30 mm	air gap
49 mm	timber cladding
417 mm	total structural thickness

Table 6: Structural layers of the intermediate floor structure in case D.

Thickness	Layer
15 mm	floor surface
50 mm	anhydride
20 mm	sound absorbing layer
20 mm	Insulated installation layer
100 mm	concrete (ballast layer)
140 mm	massive timber (cross-laminated)
35 mm	installation gap
30 mm	sound absorbing layer, fire resistant-insulation
15 mm	gypsum board
425 mm	total structural thickness

External wall solutions in *RunkoPES 2.0* are fairly similar to the built example but no exact match is found. An internal installation gap is not suggested in any detail and on the outside is typically a gypsum board with wind barrier characteristics or a layer of 50 mm thermal insulation. *Dataholz* type awrhhi07a is the most similar but requires changes in layers and dimensions. The French collection includes one close match, external wall type 2. Missing is the external paper. Wall type AW2 of the German collection could be applied with modifications: the internal installation gap is missing as well as the OSB-board, and on the outside the detail includes a gypsum board instead of hard thermal insulation. The closest match to the intermediate floor as built is found in *Dataholz*: structure gdmtxa01a. However, it would require changes in materials and dimensions. None of the other collections include any intermediate floor structure close to the as built.

4. Discussion

The comparison of built cases to national collections of pre-designed details illustrates opportunities and barriers for their applicability in practice and needs for improvement.

Among discussed built structures and joints, only a few close matches were found. These include the intermediate floor in case A matching with structure VP802BRL *RunkoPES 2.0*, the external wall of case B matching with details in the French *CCB* and German *G4*, and the structure of case D matching with external wall type 2 in CCB. Some matches requiring only minor modifications of pre-designed details are found for both external walls and intermediate floors. Similar joint solutions could not be found or joints do not exist in the selected collections. The Swiss building proved the most unique with the intermediate floor structure unfamiliar to five out of six collections.

Table 7 presents a matrix of matches between structures as built and pre-designed details. Most hits were received for *Dataholz*. However, the majority of these would require changes to both layers and dimensions, which cannot be made to available material. Most hits requiring only minor changes were received for the German collection with details suitable for both the Finnish multi-storey apartment house and the German office building in CLT.

Table 7: Results of comparing structures as built to available material in selected collections of pre-designed details. The matrix indicates whether a corresponding structure could be found and if it was a close match or requires minor or more modification (mod.). However, only CAD-objects provided by *CCB* and *RunkoPES 2.0* were possible to modify according to need.

Project	*Baubook*	*Dataholz*	*CCB*	*G4*	*LBS*	*Runko-PES 2.0*
External wall case A	-	-	Minor mod.	Minor mod.	-	Minor mod.
Intermed. floor case A	-	Minor Mod.	-	Minor mod.	-	Close match
External wall case B	-	Mod.	Close match	Close match	-	Mod.
Intermed. floor case B	-	Mod.	Minor mod.	Minor mod.	Minor mod.	-
External wall case C	-	Mod.	Mod.	Minor mod.	-	Mod.
Intermed. floor case C	Mod.	Mod.	-	Minor mod.	Minor mod.	-
External wall case D	Mod.	Mod.	Close match	Mod.	-	Mod.
Intermed. floor case D	-	Mod.	-	-	-	-

The performance of selected collections in this study varies. *RunkoPES 2.0* is developed to aid designing and building multi-storey apartment houses in Finland. Based on the results of case A it fits the purpose. However, details matching the Swiss houses were not found. As the details are planned for demanding fire classes, neither were details matching e.g. solutions with visible CLT. The *Baubook* is developed for ecological passive house design. Of presented buildings, only the Finnish case aimed for passive house level of energy efficiency but matching structures or joints could not be either found or reconstructed in *Baubook*. The German collection is designed to cater the needs of designing multi-storey timber structures up to 13m height of upper floor level and proved useful in this study with solutions applicable to most cases. The Swiss collection performed poorly in this study. Even though it contains designs for 323 intermediate floors, only two close matches could be found: the CLT-structures. The lack of other structural types and joint details additionally limits its applicability. *Dataholz* is one of the most extensive collections with a large variety of solutions applicable to different fire classes. However, only one direct match was found requiring minor modification. Several similar structural types as the built examples were found, but with differences in both materials and the structural thickness of one or several layers. Based on this study a common library could be created, but an efficient use requires modifiable material.

The results are based on four exemplary cases and selected structures. The buildings represent different fire classes and typologies, not always matching the objective of the discussed collections. Despite this inconsistency, the study does illustrate the complexity of and need for streamlining timber construction. The study also included discussions with designers and stakeholders of the built projects. These revealed that details as built are often the result of internal or collaborative development between project partners, based on earlier experiences and also undergoing further optimisation work. In terms of lean construction, this is in line with the principle of working with known partners and using components optimized throughout the production process. On the other hand, even if the studied solutions are beneficial for the partners involved, they might not be as suitable for e.g. new manufacturers entering an established consortia. In terms of public procurement and enhancing the competitiveness of timber-building, this finding is a barrier. Without established common solutions it is challenging to receive comparable offers.

5. Conclusions

This paper presented a case study comparing two structural and three joint details of four timber-buildings across Europe to selected collections of pre-designed details. The cases demonstrate various individual approaches to timber design, correct craftsmanship with respect to current norms and proper structural protection of timber. Evaluated collections include the Austrian *Baubook* and *Dataholz*, the Finnish *RunkoPES 2.0*, the French *Catalogue Construction Bois*, the Swiss *Lignum Bauteilkatalog Schallschutz*, and *German Erarbeitung weiterführender Konstruktionsregeln/-details für mehrgeschossige Gebäude in Holzbauweise der Gebäudeklasse 4*. The aim was to evaluate whether the buildings could have been designed using ready-made material.

The results show a large variation. The smallest amount of details corresponding to solutions as built were found in the *Baubook* and Swiss collection. Structural solutions comparable to the Swiss case could not be found in either one. The German collection proved the most applicable with several solutions close to the built benchmarks despite differences in fire class. Based on these results a common ground exists but applicability in practice requires modifiable material. Even if the collections offer a broad variety of exemplary details corresponding to current building regulations, in discussed cases, these were not used as a basis for the design. Details as built are often the result of a collaborative development process between project partners and based on earlier experiences. This result is in line with lean culture suggesting work with known partners and the use of standard components optimized for the production process. However, such a working method limits the options for new manufacturers or partners to enter an established consortia and creates additional costs to new collaboration. From the viewpoint of European wide procurement and the competitiveness of timber building the findings are problematic. Without allowing for established common solutions clients are unable to receive comparable offers.

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Towards Unified Sustainable Buildings Rating System Categories through Assessing Buildings' Life Cycle Sustainable Requirements

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Summary

Sustainable building rating systems encompass multidimensional criteria. Different geopolitics, regions, and microenvironments incentivized sustainable developers to generate hundreds region-based environmental and sustainable building rating systems. Sustainable building rating systems are categorized differently based on many drivers such as developers' interests and specialties, regional demands and constraints, environmental impact categories, and economic and social aspects. Two different approaches are utilized in structuring rating systems: qualitative and quantitative. The qualitative approach is based on monitoring or assessing buildings, giving scores to parameters that are measured qualitatively or quantitatively, and aggregating the scores to yield one score that represent the building performance. Building performance score can be compared relatively to other buildings performance that are developed using the same tool, or against a national reference set by decision makers. The quantitative approach is based on assessing the whole life cycle of a building based on quantitative input and output data of the flows of several parameters such as materials and energy. The authors reviewed and benchmarked eleven well-known qualitative rating systems. Water, Energy, Material, Sustainable sites and Indoor Environmental Quality categories were common categories among the compared tools. Moreover, the sustainability three dimensions: environmental; social and economic aspects were not treated equally by the rating tools. Rating systems vary in terms of buildings typology, users' types, life cycle phases analyzed and outcomes. Hence, buildings performance constructed using different rating tools cannot be compared and benchmarked due to the variations of the categories structures and weights of the different tools. This paper aimed to lay down unified balanced categories structure that can be utilized widely based on buildings' life cycle. The derived categories were further benchmarked against sustainability core indicators of ISO 21929-1: 2011.

Keywords: Buildings' life cycle, sustainable building rating systems, ISO 21929-1: 2011.

1. Introduction

1987 was the cornerstone year in changing global mind-set towards sustainability as many reports concluded that following the same traditions in businesses practices would lead to environmental calamity. Since then, sustainable development was adopted in many fields with different level of implementations. Researchers and professionals undertake their share of responsibilities in the built environment mainly to reduce the environmental harmful impacts namely greenhouse gas emissions and global warming. Construction in general disturbs the eco-balance; therefore, actions are needed to mitigate time needed to set back the interrupted environment to balance. As a result, many sustainable organization, such as BRE Building Research Establishment (UK), United States green building council (USA), Building Green, and World green building council were founded to commence sustainable practices in the built environments. Accordingly, over hundred sustainable and environmental rating systems were developed with various categories based on the regional demands, geopolitical thoughts and environmental needs. In practice, the rating tools are utilized with respect to natural resources management through partial or complete life cycle of buildings (planning, design, construction, occupancy and operation, demolition and disposal). The quantitative rating tools assess building systems performance holistically. On the other hand, the qualitative tools form a suite of different categories according to building function (residential, commercial, institute, healthcare…), building status (New Construction, Operating and maintenance, Existing buildings….) and building components (Core and Shell, Interior……). Categories further consist of indicators that simplify, quantify and communicate an existing concern in specific area in environmental, social, or economy domains. Indicators measure performance of one or more associated parameters and probably benchmark the performance against national standards. A parameter is a measurable or observable property which provides information about the building performance in a significantly concerned area. In general, rating tools continuously improve building performance optimization, minimize buildings' impacts on environment, set standards for buildings, raise sustainable awareness among practitioners, and enhance construction and operational management. The rating tools assess the sustainability level in buildings by setting some performance constraints and benchmarking the concerned building against the constraints and among other buildings evaluated using the same rating tool. There are several works done in comparing some of the available rating systems [1], [2], [3] and [4]. However, challenge emerges from comparing performance of two buildings assessed using different tools. In other words, would two different rating tools yield same sustainability rating for one building? Obviously, comparability is difficult because of assessors various backgrounds, various tools structures and standards demand and characteristics in different regions. Reference [5] concluded that the highest Green Star rated building is less sustainable than a LEED platinum building and BREEAM "very good" building. Thus comparing sustainability level of buildings in different regions through local sustainable rating tools is not fairly possible unless unified baseline categories govern assessments. Similar to common approaches in appraising projects financially, international stakeholders demand concerted approach in evaluating sustainability level of buildings which could be linked to buildings' value [6]. Therefore, there is a call from the global financial and real estate's markets to develop a unified framework composed of a set of categories to assess and compare sustainable performance in buildings in different regions. Consequently, [7] reported that three rating tools namely LEED, BREEAM, and Green Star considered developing unified metrics to easily compare building in different regions. OPEN HOUSE [8] and SuPerBuildings [9] projects, promoted by the European Commission and utilized international standards from ISO TC 59/SC 17 or CEN/TC 350, developed frameworks in designing and assessing sustainable buildings in Europe. SB-tool is another international generic framework that can be utilized and adjusted by a third party according to regional demands.

2. Methodology

This study compared eleven existing well-developed rating systems: BREEAM, LEED, CASBEE, Green Star, G-Seed, DGNB, PEARL, GSAS, Beam Plus, Green Mark and SB-Tool and extracted their common categories. It has to be noted that the compared systems are regarded in literature as sustainable tools although sustainability pillars, environmental, economic and social aspects, are not addressed equally in these systems and environmental performance occupies major share. The authors developed Sustainability requirements list at each buildings' life cycle stage and composed different categories based on sustainability requirements. The derived categories were benchmarked against ISO 21929-1: 2011 requirements [10] and the shared categories by the compared rating systems. The proposed categories introduced core requirements in sustainable buildings and serve towards an internationally-accepted rating system.

2.1 Rating Tools Overview

2.1.1 BREEAM

BREEAM was launched on 1990 by Building research establishment global limited ((BRE Global Ltd.) [11]. BREEAM has two schemes; country specific scheme that is applied to its local countries and international scheme that is applied to any country that is not included in the first scheme. BREEAM assesses different building types; New Construction, Offices, Industrial, Retail, Prisons, Educational, Healthcare, Law court, Residential Institutions, Nonresidential institutions, Leisure, and Data centers. The system has ten categories which are divided into sets of credits. Some of the credits are compulsory "Minimum Standards". The system consists of six main categories.

2.1.2 LEED

The United States Green Building Council (USGBC) commenced a pilot version of LEED (Leadership in Energy and Environmental Design) rating tool in 1998. The first version was released in 2000. Since then, the tool has developed till the release of version four in 2013. Nowadays, it is considered as evaluation tool of green buildings in many countries beside the USA [12]. There are 65.044 LEED certified projects worldwide [13]. LEED assesses different building types; New Construction, Hospitality, Data Centers, Schools, Retail, Healthcare, Warehouses and Distribution Centers and Homes. LEED is structured of eight categories, each of which has a set of prerequisite and optional Credits/Indicators.

2.1.3 CASBEE

CASBEE was initiated at 2004 by Japan Green Build Council (JaGBC) / Japan Sustainable Building Consortium (JSBC) [14]. CASBEE assesses different building types; Offices, Schools, Retails, Restaurants, Halls, Factories, Hospitals, Hotels and Homes. CASBEE developed its unique weighting system by comparing Built Environment Quality (Q) to Build Environment Load (L). The Built Environment Efficiency (BEE) is represented by (Q/L).

2.1.4 Green Star

Green Star was first launched in 2003 by The Green Building Council of Australia (GBCA). Green Star has different versions to assess specific building type: Educational, Industrial, Healthcare, Multi-unit residential, Office, Office interiors, Retail, or Public buildings. It is the only domestic rating system in Australia, and by 2015 the system has been used to assess over 1000 buildings and communities across Australia [15]. The system design is influenced by BREEAM and consists of into nine categories. Each indicator is evaluated and assigned a score, except the conditional requirement scores, which have to be fulfilled but no score is given.

2.1.5 G-Seed

The Green Standard for Energy and Environmental Design (G-SEED) is South Korea's green building certification system, which was introduced targeting multi-residential buildings to be co-supervised by the Ministry of Land, Infrastructure & Transport, and the Ministry of Environment [16]. Developed in 2002, G-SEED is a domestic certification system evaluating the environmental-friendly buildings for residential building types as multi-residential housing and detached house, and nonresidential building types as Office, School, Retail, Hotel, and other buildings divided as new and existing constructions. Green Mark has eight categories.

2.1.6 DGNB

The German Sustainable Building Council (DGNB for Deutsche Gesellschaft für Nachhaltiges Bauen) is a comprehensive rating system that assesses buildings as well as urban districts towards complying with sustainability objectives. The DGNB System covers key aspects of sustainable building: environmental, economic, sociocultural, and functional aspects, technology, processes, and site. DGNB system assesses performance of buildings or urban districts throughout their life cycle rather than assessing individual measures [17]. The system consists of six main categories/evaluation area.

2.1.7 Pearl

Established in 2010, Pearl Rating System is a key initiative for Estidama which means 'sustainability' in Arabic. The ultimate goal of Estidama is to put Abu Dhabi as a leading example of sustainable urbanization [18]. The Pearl Rating System is built on four pillars that are; Environment; Economic; Culture; and Social to assess the project's performance and provide design guidance and detailed requirements for different buildings' typologies including General buildings, Offices, Retails, Multi Residential Units, Schools, Mix-use buildings. The Pearl Rating System is organized into seven categories.

2.1.8 GSAS

Global Sustainability Assessment System (GSAS) was developed by the Gulf Organization for Research & Development (GORD) for the State of Qatar and released for use in 2012 [19]. GSAS currently is used to assess the sustainability of different building types such as Commercial, Core and Shell, Residential, Education, Mosques, Hotels, Light Industrial, and Sports Building types. The system design has been affected by existing sustainable building rating systems, i.e. LEED. GSAS has a unique rating system, as each indicator is assigned a score of -1, 0, 1, 2, or 3 points based on its sustainability level. The current version of the system consists of eight categories.

2.1.9 BEAM Plus

Building Environmental Assessment Method (BEAM), a rating tool for overall building performance, was first established in 1996 with assessment methods that were mostly based on UK Building Research Establishment's BREEAM. The process of certifying BEAM Plus projects, accredits

BEAM Professional (BEAM Pro), BEAM Affiliate (BA) and BEAM Assessors (BAS) is administered by the Hong Kong Green Building Council Limited (HKGBC). The HKGBC was established in 2009 with a main goal to promote the standards and developments of sustainable buildings in Hong Kong, a country with high density of population and tall buildings [20]. The BEAM Plus rating tool has six main categories/aspects.

2.1.10 Green Mark

Green Mark was developed by the Building Construction Authority of Singapore in 2005 and is supported by the country's National Environment Agency [21]. It aims to evaluate environmental impact and performance of buildings, and to provide a comprehensive framework for assessing the environmental performance of new as well as existing buildings in order to promote sustainable design, construction, and operations practices in buildings. It assesses Residential and Non-residential buildings, Parks and other infrastructure scoping their pre-design, design, construction, commissioning, and operational phases. Green Mark consists of five categories.

2.1.11 SBTool

SBTool is a generic framework for assessment of building performance which may be used by third parties to develop rating systems relevant for a variety of local conditions and building types. SBTool may also be regarded as a rating system toolbox [22]. The SBTool offers a philosophy that a rating system must be adapted in accordance with local conditions to achieve meaningful results. The system is therefore designed as a generic framework, with local non-commercial organizations being expected to define local context conditions and to develop appropriate weights and benchmarks. Table 1 summarizes rating systems' basic information.

Table 1: Rating systems' information

Rating Tool	Origin	Year Established	Latest Version	Website
BREEAM	UK	1990	2014	[11]
LEED	USA	2000	V4/2013	[13]
CASBEE	Japan	2004	2014	[14]
Green Star	Australia	2003	Office V3, rest V1	[15]
G-Seed	Korea	2002	2011	[16]
DGNB	Germany	Jan. 2009	2014 (international version)	[17]
PEARL	UAE	2010	2010	[18]
GSAS	Qatar	2012	2012	[19]
BEAM Plus	Hong Kong	1996	2012 (new building)	[20]
Green Mark	Singapore	2005	2013	[21]
SB-Tool	Canada	2007	2015	[22]

2.2 Buildings' life cycle sustainable requirements

Typical buildings' lifecycle is divided into six phases as summarized in Fig. 1. It starts with the planning phase followed by design, and construction. The first two phases are the most important in determining how a building will perform throughout its life-cycle, and if sustainability was a desired goal, then how sustainable the building can be. To answer the later question, the authors listed requirements to be addressed during each of the six life-cycle phases in order to have a holistic approach for a sustainable development, Table 2. These requirements act as a frame work that could be utilized to generate categories and indicators to be measured or evaluated in a sustainable rating system. Therefore, any sustainable building rating system should be able to address these requirements either as a category, an indicator, or a variable under indicators. It can be observed that the planning and design phases list nineteen requirements which can be evaluated by design, site investigation and analysis, simulations, and compliance to local or international building codes. Nevertheless, a design decision that is made during these two phases is crucial since it will be significantly costly or difficult to change once the building move into the next phase in the cycle, i.e. the construction phase. The other four life-cycle phases, list fifty three requirements that are mostly operational and management, and can be measured and verified with instrumentation and metering.

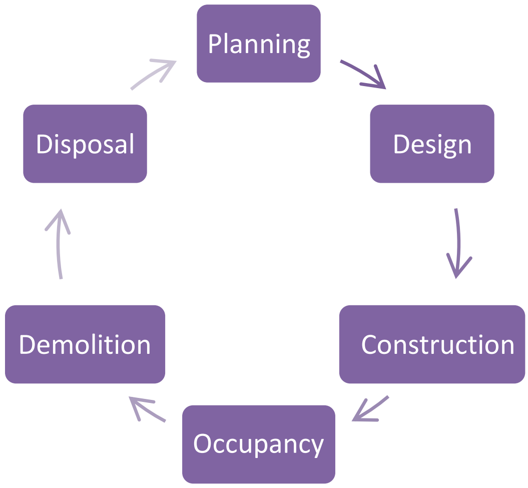


Figure 1: Buildings' life cycle

Table 2: Buildings' life cycle sustainable requirements

	Planning	Design	Construction	Occupancy	Demolition	Disposal
1	Efficiency	Safety design	Minimize waste	Management Cost	Labor Cost	Labor Cost
2	Life cycle profit analysis	Materials choice	Materials consumption and Cost	Maintenance Cost	Equipment Cost	Equipment Cost
3	Life cycle cost analysis	Energy Performance	Water consumption and Cost	Waste Management	Energy Consumption	Waste disposal costs
4	Conservation of cultural and natural heritage	Environmentall y conscious design	Energy consumption and Cost	Water production and Cost	Materials Sorting and classifications	Energy Consumption
5	Land Use	Waste Reduction	Labor Cost	Materials consumption and Cost	Materials Disassembly	Waste Management
6	Eco-environmental sensitivity	Building Code Compliance	Equipment Cost	Energy consumption and Cost	Demolition Plan	Land Rehabilitation and remediation
7	Ecological assessment	Operational Planning	Security and Safety	Labor Cost	Economy	Materials Recycle/ Reuse
8	Air Assessment		Labor Health and Safety	Security and Safety	Public Comfort	

9	Water Assessment	Construction efficiency	Ecological Impacts	Noise Pollution
10	Noise Assessment	Public safety	Water Pollution	Ecology Disturbance
11	Waste Assessment	Land use pollution	Noise Pollution	Biodiversity Disturbance
12	Municipalities and Governing regulations	Biodiversity protection	Air Pollution	Environmental regulations and policies
13		Air emission and pollution	Environmental regulations and policies	Air Emissions and pollution
14		Noise pollution	Facilities Management	Efficiency
15		Discharge and Water Pollution		
16		Public comfort		
17		Ozone protection		
18		Environmental regulations and policies		

3. Discussion

Common categories addressed in the eleven compared rating systems are shown in Table 3. It is noteworthy that subjects of some categories are already addressed in some rating systems at the level of indicators. For instance, management is embedded under various indicators in LEED and does not have separate category. Water, Energy, Material, Sustainable sites and Indoor Environmental Quality categories were common categories in the compared tools.

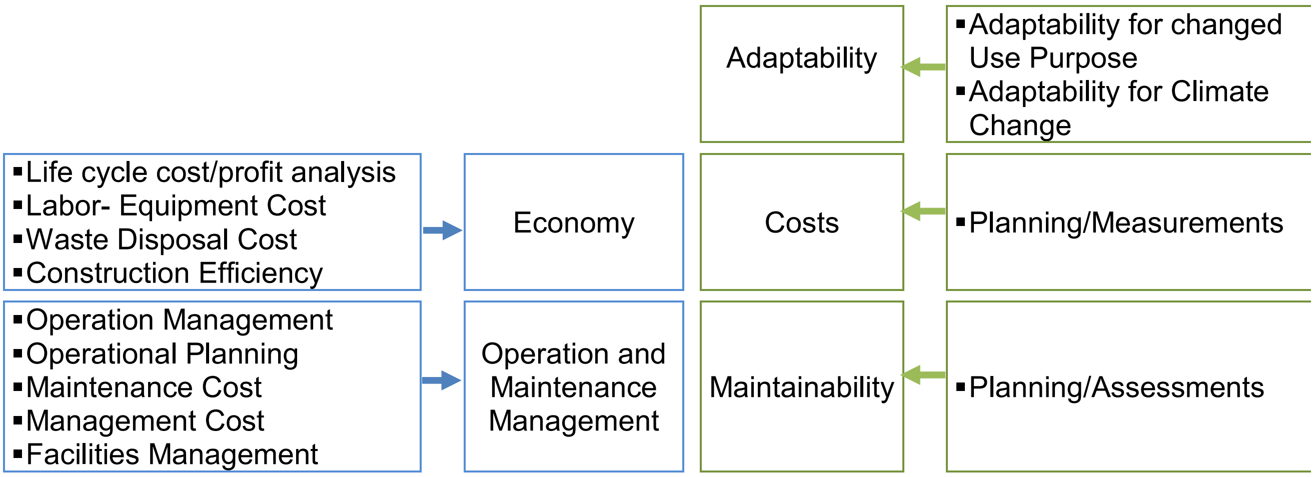
Table 3: Environmental rating systems categories

Rating Tool	Location	Transport	Sustainable Sites/ Land Ecology	Water Efficiency	Energy	Atmosphere	Pollution	Waste	Materials	Indoor Environmental Quality	Health and Wellbeing	Innovation	Regional Priority	Management	Quality of Services
BREEAM		√	√	√	√		√	√	√		√	√		√	
LEED	√	√	√	√	√	√			√	√		√	√		
CASBEE			√	√	√	√			√	√					√
Green Star			√	√	√		√	√	√		√		√	√	
G-Seed	√	√	√	√	√	√			√	√				√	
DGNB	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
PEARL	√		√	√	√				√	√		√		√	
GSAS			√	√	√			√	√	√				√	
BEAM Plus			√	√	√				√	√		√			
Green Mark				√	√	√		√	√	√					
SB-Tool	√		√	√	√	√			√	√					√

Items in Table 2 were classified into categories according to the sustainability paradigm which addresses the environmental, economic and social dimensions. Analyzing the sustainability checklist, the authors derived the following main categories that can be included in any general unified sustainable rating system (Table 4, left column): Regulations, Air Protection, Water Conservation, Energy, Material, Waste Management, Land and Biodiversity Protection, Human Comfort and Socialization, Economy, Operation and Maintenance management. Benchmarking the proposed categories against ISO 21929-1: 2011 Core Indicators is shown in Table 4.

Table 4: Comparison between the proposed categories and ISO 21929-1: 2011 Core Indicators.

Buildings' Life Cycle Sustainability Requirements		ISO 21929-1: 2011 Core Indicators	
▪Building Code Compliance ▪Municipalities and Governing regulations	→ Regulations	Access to Services ←	▪Public Transportation ▪Personal modes of Transportation ▪Green and Open Spaces ▪User Basic Services
		Aesthetic Quality ←	▪Integration with the Surrounding ▪Impact of Building in Site ▪Local Concerns
▪Land Use- Remediation ▪Biodiversity Protection ▪Ecological Assessment ▪Environmental Policies ▪Eco-environmental Sensitivity ▪Environmentally Conscious Design	→ Land and Biodiversity Protection	Land ←	▪Site Selection
		Accessibility ←	▪Building Site-Building
▪Air Emission and Pollution ▪Ozone Protection	→ Air Protection	Harmful Emissions ←	▪Depletion of Stratospheric Ozone Layer
▪Energy Consumption ▪Energy Performance- Cost	→ Energy	Nonrenewable Resources ←	▪Use of resources
▪Consumption-Sorting ▪Disassembly-Choice ▪Recycle-Reuse-Cost	→ Materials		
▪Consumption-Production ▪Pollution-Assessment-Cost	→ Water Conservation	Fresh water ←	▪Use/Consumption
▪Management-reduction ▪Assessment-Cost ▪Demolition and disassembly	→ Waste Management	Waste ←	▪Production
		Indoor Environment ←	▪Indoor Conditions ▪Indoor Air Quality
▪Noise Assessment-Pollution ▪Security and Safety Design ▪Public/labor Safety- Comfort ▪Conservation of Cultural and Natural Heritage	→ Human Comfort and Socialization	Safety ←	▪Stability ▪Resistance ▪Fire Safety
		Serviceability ←	▪Planning/Measurements



Comparing the proposed categories to ISO core indicators, it is seen that Land, Water, Harmful emissions (Air Protection), Non Renewable Resources (Energy & Materials), Waste, Cost, and Maintainability are common categories. Aesthetic Quality, Accessibility, Indoor Environment, Safety, and Serviceability can be grouped under Human Comfort and Socialization category. Different building assessing perspectives such as developers' and users' interests, and building boundaries along with its components, inputs, and outputs can expand this study to form more sophisticated global sustainable buildings rating tool platform.

4. Conclusions

This study analyzed eleven well know sustainable rating systems and extracted the common categories. On the other hand, the authors itemized sustainability requirements throughout projects' lifecycle phases and categorized the requirements in light of sustainability domains. The unified categories were Regulations, Air protection, Water conservation, Energy, Material, Waste management, Land and Biodiversity protection, Human comfort and Socialization, Economy, and Operation and Maintenance Management. The proposed categories are well correlated against ISO 21929-1: 2011 Core Indicators. The proposed categories can be expanded to include regional and local demands.

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User-friendliness of current building environmental impact assessment tools: an architect's perspective

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Summary

In the building sector, the global environmental impact of buildings is gaining attention. This environmental impact includes all impacts related to the building (materials) throughout the entire life cycle. A number of tools to assess the environmental impact of buildings as a whole has already been developed, usually with an underlying life cycle approach. As architects are a central actor in the design process, they are responsible for the building design and the accompanying environmental impact. Therefore, in the future, they will most likely perform such an environmental impact assessment (EIA) during the design process. So, environmental impact assessment tools should be adapted to the architect's work method and practice. In this context, a comparative evaluation of the user-friendliness of four existing EIA tools is performed from a Flemish architect's perspective. An evaluation framework and a reference building are used to obtain comparable results on the architect-friendliness of these tools. The findings indicate that architect-friendliness is not sufficiently taken into account yet in the existing EIA tools. Therefore, a series of suggestions for improvement of the current tools and guidelines for the development of new EIA tools, oriented to usage by architects, is included.

Keywords: Architect-friendly, Building assessment, Design supportiveness, Framework, Tool evaluation

1. Introduction

The focus of sustainability in the building sector is shifting from energy efficiency of buildings towards global environmental impact of building design [1-4]. To assess the environmental impact of a building during its lifespan, all environmental impacts along the life cycle of the building and its composing materials should be taken into account. Life Cycle Assessment (LCA) is the most objective and quantitative methodology to calculate these environmental impacts. A number of LCA-based tools for environmental impact assessment (EIA) on whole building level has already been developed on different assessment levels: building material level, building component level and even on a whole building level [5, 6]. Tools for impact assessment on a whole building level appear to be the most suited tools for architects to use along the design process [5]. However, studies have already demonstrated that the uptake of assessment tools by architects is limited [7, 8], mostly because architects do not consider such an assessment as part of their work package (too complex, too time-consuming) or because they are simply unaware of the existence of these tools [9]. These aspects provoke that architects are often unfamiliar with these assessment tools and that the usage during the design process is not prevalent. A similar problem is encountered with the energy performance calculations (under the Energy Performance of Buildings Directive [10]). In current Flemish practice, these calculations are often outsourced to an expert at the end of the design stage, which only allows (limited) remediation [11]. To stimulate architects to assess their project from early design on, more attention to the architect's work method and user needs is necessary in the development of these tools [12]. Since it is highly probable that in the future architects will have to consider the environmental impact of their designs, in analogy with the energy performance that they already have to take into account nowadays, the need for more architect-adapted EIA tools will increase in the future [13].

2. Methodology

2.1 Tool selection

To assess the degree of architect-friendliness (i.e. user-friendliness from the architect's perspective) of existing LCA-based EIA tools for buildings, a number of tools have to be selected for testing. As Flanders (or Belgium) does not have a tool for environmental impact assessment on a building level yet, tools from other countries are chosen for evaluation. Elodie® (France) [14], Eco-Bat (Switzerland) [15], Greencalc⁺ [16] and MRPI® Freetool (Netherlands) [17], all Western-European tools that are suitable for the Flemish building context and available for free or as a demo version, were chosen for evaluation and comparison. A more elaborated tool description can be found in section 3.1.

2.2 Design of a reference building

To test and compare the architect-friendliness and usability during the design process of these EIA tools, a reference building (typical Flemish dwelling) has been developed. The reference building is detailed per design phase (conceptual design, preliminary design, detailed design, tendering and construction) to simulate an actual design process (based on [18]). For the reference building, a simple design project and corresponding design process are assumed; for more complex projects, further research is needed. The design process and available design data are illustrated in Fig. 1. During conceptual design, an idea is formed with some first sketches of the (maximum) building volume and form and floor area. In preliminary design, different design options are evaluated by the architect through sketches, 3D volume studies and (2D) plan drawings. The architect usually draws sketches or plans with solid walls with a thickness, but without details on the exact wall composition. In detailed design, a final solution is obtained and design parameters are developed in more detail. Once the design is finalized, the building permit file is put together and submitted. In the tendering phase, the architect starts detailing the execution plans and developing the tendering specifications and the bill of quantities. The construction phase is technically not a part of the design process as the design is finalized and the building permit is obtained. However, minor changes to the design (internal plan organization, furnishing, …) may still occur. These (intermediate) design data are used as input in the tools, which enables comparison of the usability from the architect's perspective and the design supportive value of the tools in different phases of the design process.

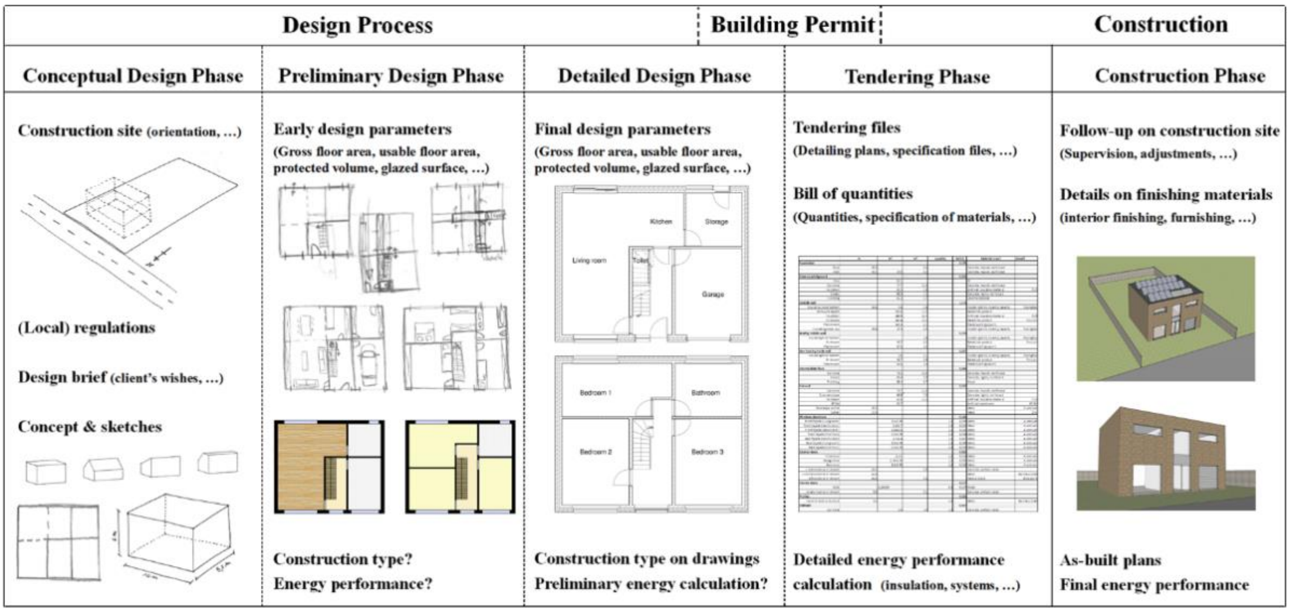

Fig. 1: Reference building and the design parameters per design phase

2.3 Tool assessment with evaluation framework

In 2010, Weytjens and Verbeeck [11] developed an evaluation framework to define the concept “architect-friendliness” of thermal performance simulation tools, based on findings from a large-scale survey (N = 269) and semi-structured interviews with Flemish architects. This framework is used as a starting basis, since it is already adapted to the Flemish context. However, in order to adapt it to the field of environmental impact assessments, it is complemented with criteria from existing studies on the comparison of environmental impact assessment tools [5, 6, 19, 20] and fine-tuned with the results of a large-scale survey among 364 Flemish architects and five semi-structured interviews with Flemish architects [21, 22]. The final framework consists of five main themes: 1) data-input, 2) output, 3) interface, 4) usability in design process and 5) general tool characteristics, each with a number of sub-themes and criteria. These criteria are assessed using a 0 to 4 rating scale. For the tool comparison, the design parameters of the reference building are entered in the four software tools, with the criteria of the evaluation framework kept in mind. In this research, only the modules of the tools regarding the material use are studied in detail, the other modules are only briefly examined. During evaluation, the tools are compared on their design supportive value and usability along the design process. As the focus is on the architect-friendliness and applicability of these tools during the design process, the exact outcome of the assessments (environmental scores etc.) is not relevant for this paper. The final result per tool is shown section 3.2 and discussed in section 4.

3. Results

3.1 Description of the tools

Four tools (Elodie®, Eco-Bat, Greencalc+ and MRPI® Freetool) are chosen for evaluation on their degree of architect-friendliness. After a brief literature review, the most important tool features are presented in Table 1. All tools are intended for evaluation on a building level and handle the environmental impact assessment of the materials used in the building. Most tools also claim to be suited for use in early design stages and by the architect. In the next sections, the tools and their functions are discussed in more detail.

Table 1: Overview of some tool features for the four tools

	Elodie® (France)	Eco-Bat (Switzerland)	Greencalc+ (Netherlands)	MRPI® Freetool (Netherlands)
Tool type	Web-based, save on the internet	Download and save on computer	Download and save on computer	Web-based, save on computer
Availability	30-day free demo	30-day free demo	Free full version	Free full version
Language	French (and English)	French, English, German, Italian	Dutch	Dutch
Version	V2 (limited)	4.0 (limited)	4.2 (full)	Beta 1.1 (full)
Main database	INIES, CSTB	Ecoinvent	NMD (outdated)	NMD (recent)
Impact categories	15	4 (+ expendable at cost)	17	11
Assessment level	Neighbourhood, building block, building	Building	Neighbourhood, building	Building
Modules in tool	Material, energy, water, waste, construction site, transportation, acoustics, indoor air quality, costs	Material, energy use, technical systems	Material, energy, water, transportation (only on level of neighbourhood)	Material (and fixed furnishing)
Claims to be suited for:				
Early design?	Yes	Yes	Yes	Not really
Architect?	Yes	Yes	Yes	Yes

3.1.1 Elodie®

The data-input starts with a building wizard in which basic characteristics such as lifespan, building type, floor area, number of occupants, location (restricted to locations in France), … can be entered. Construction type, current phase of the design process etc. can also be selected (not mandatory), but do not have direct consequences for the impact calculation. However, this would be a useful feature, as it could be used to provide a first indication of the impact in early design.

The input procedure is rather intuitive and simple. In the material input module, the user can choose between three types of studies in order to match the different user requirements [23]: 1) summary study, 2) simple study and 3) detailed study. Depending on the type of study, the material quantities and types are predefined or need to be specified by the user. These study types roughly correspond to the three design phases (conceptual, preliminary and detailed), which enables usage during the design process. Materials can also be imported from a CAD software by using an intermediate step (program Eve-BIM, option not available in demo version).

In contrast to the input, the output is not adapted to different design phases, which limits the design supportive value (especially in early design). There is a wide range of output possibilities available: numeric values per impact category, graphs on a building level or on a component level per impact category, …. However, research [22] has indicated that (Flemish) architects do not really care for output per impact category; they prefer a comparison of different building alternatives to each other or to a benchmark.

The interface is clearly structured, using a tree structure on the side of the screen to navigate. It is flexible to use, but no 2D-drawings or 3D-models of the building are implemented in the tool.

The tool is quite usable along the design process, due to the different calculation types (summary, simple, detailed). Multiple buildings can be created and compared quite easily (copying and altering a project). However, the difference between the impact of two alternatives is not clear until

the output is generated again (no real time feedback). No benchmark, target value or reference building is available and no design optimizations are generated.
In general, the tool is easy to learn and simple to use. For the input, the level of background knowledge is limited, but for the output interpretation, some background knowledge is required. Elodie® is suited for different building types. The tool handles energy calculation (can be imported), but data have to be entered twice (once for energy and once for materials). Due to the different calculation types, the time spent on the tool can be spread over the design process.

3.1.2 Eco-Bat

As data-input, the component geometry and material specifications have to be entered. No default components are available, the materials have to be specified by means of material or product specific data sheets. In the demo version, a rather limited database (about 30 materials, in contrast to the full version with about 150 materials) is implemented. Therefore, the material choice is quite restricted for certain elements.
The output can be obtained in many different formats: tables with numeric values (per element or for the whole building) or graphs per life-cycle phase, per element, per material, per impact category. The user can choose to include the transportation (generic Swiss data or user-specific data) and the replacement phase, which requires some basic insights in the LCA-methodology. From the wide variety of output formats, some information for decision making can be retrieved, but no design supportive suggestions or optimizations are generated. Since most output is expressed per impact category, this is of little added value for architects as their background knowledge is limited. Multiple design alternatives can be compared on a whole building level (not in depth), but they cannot be generated at the same time and compared. No benchmark, target value or reference building is incorporated in the tool. So, the output is not very suitable for (Flemish) architects as an argument to convince the client.
The user-interface uses standard graphical drawings to represent the building elements, but besides that no visual aids are used. The interface is structured in different tabs on top of the screen (three input tabs and three output tabs) and is easy to navigate.
The tool only provides one calculation mode, in which no default values for early design are included. Therefore, the tool is not really suited for early design. The user could start the assessment based on rough measurements and basic materials of the building components, which can be specified later on, but the tool is not specifically developed for that.
In general, the tool is easy to use and clearly structured. For the input of the components and materials, no specific background knowledge is needed. For the output interpretation, insights in the principles of LCA are necessary (selection of impact categories, life-cycles phases, …). The tool can be used for different building types, both new construction and renovation. The energy module of the tool cannot be imported in the demonstration version, but it is possible in the full version. If no full calculation of the energy use can be performed, a predefined set of energy performance related values can be generated (defaults), in contrast to the material module.

3.1.3 Greencalc$^+$

The data-input starts with a building wizard, in which information on the building neighbourhood and further location specifications (restricted to the Netherlands) are entered. For the building itself, four aspects have to be defined: materials, energy, water and mobility (no influence on building impact calculation). In the project, status (sketch, preliminary, detailed design, etc.) and calculation options (indefinite or definite) are provided, but these do not affect the further calculation or the obtained results. In the building wizard (for early design phases), the building geometry is modelled according to (rough) measurements and the user can already impose some targets/concepts. No visual support is present in the building wizard, but data such as façade surface, gross floor area, etc. are generated automatically. Later on, these predefined data and imposed concepts can be specified by the user, which is also recommended in the wizard (otherwise material quantities are overestimated). Materials (and sometimes components) can be chosen from a database (with about 500 materials and 35 predefined components) and dimensions or quantities can be entered or altered. In addition, the user can define new materials or components.

The output is provided on neighbourhood and building level. Both tables and graphs are provided. The data in the tables are expressed in environmental costs per building aspect (material, energy and water). In addition, a total score is provided. An environmental index, the MIG score, is calculated for each building aspect and the total score (cost of the reference building divided by the cost of the own building design). If the MIG score > 100, the building performs better than the reference building (at a lower environmental cost) and vice versa. The MIG score is also used for graphical visualization.

The building wizard uses a sequence of five steps to model the building (roughly), which are easy to complete. After finalization of the wizard, the basic user interface opens. The interface is simple and uses a tree structure on the left side of the screen. The top level represents the neighbourhood, the lower levels represent the building, subdivided in materials, energy, water and mobility.

The tool can be used from early design on, due to the wizard, the use of target values, concepts, example buildings, etc. Further in the design, the user can go into detail in the material, energy and water modules of the tool by overriding and complementing the conceptual information. The quantity and thickness of the materials from the database can be adapted and new materials or components can be added. The building design can be compared with the reference building and with the targets which have been set on beforehand (e.g. the desired MIG score). Besides that, it is also possible to replace the reference building with another design option, enabling the comparison of two design alternatives.

The tool is freely available on the internet, but further development stopped around 2012. Therefore, the results are no longer up to date. However, the usability and user-friendliness of the tool is rather good in general. Greencalc⁺ can be used for different building types and different phases of the design process. Therefore, the tool can be used along the design process, so that only a limited amount of time is spent during each design phase. However, improvements could be made on the use of visual aids and data importation.

3.1.4 MRPI® Freetool

In the input-section of the tool, building and construction materials and fixed furnishings are input parameters. Materials have to be selected from a list (per component) and quantities have to be entered in predefined units (m^2, m^3, …). No new materials can be added nor can data be imported from other software packages. No default material quantities are available. Therefore, the tool is mostly suited for the building permit phase (which is also the targeted phase), when materials and quantities are more or less known, but even then the tool is not very user-friendly.

The output consists of two tabs, in which the output can be generated in different formats. The first tab consists of a table with numeric values, expressed per impact category. The second tab consists of several graphical formats: the user can generate a graph on the building level with ratios (percentages of the total impact) for the impacts of the different building components, but information can also be deepened within a certain component, in which the impact ratios of the individual materials used in this component are shown. A one-number score (MPG-value) is

provided in the output of the tool. If this value > 1, the design has a higher environmental impact for the materials than an average building: if the value < 1, the design performs better than an average building, but no suggestions on how to improve the design are included. When a benchmark for the MPG-score will be implemented (future goal of the tool), the tool outcome will give the architect an argument towards the client to strive for a better performance.
The user-interface has a rather simple structure, with drop-down lists per building component, in which the user can select the appropriate material (predefined) and add the quantity.
The tool is not suited for use in early design, as no defaults or predefined components or structures are implemented. Data can easily be altered in the input tab and users can go back a few steps. The tool is not equipped with a reference building, but the MPG-score is calculated in the outcome, which enables comparison with the average performance of buildings. Besides results on the environmental impact of building materials, no other results (e.g. information on energy and water consumption) can be generated (limited scope).
In general, the tool is easily accessible on the internet and suited for a wide range of building types, but the added value for usage along the design process is limited. No link with other software or drawing tools is present. It is a stand-alone tool, suited to calculate the environmental impact of building design once the design is practically finished and all materials and their quantities are known.

3.2 Tool assessment with evaluation framework

The final evaluation (rating scale from 0-4) of the four tools on their architect-friendliness is shown in Table 2 and a global overview is presented in Fig. 2. The theme scores are calculated as an average score of all criteria within the theme and the total score is the average of all five theme scores. When interpreting these scores, it should be taken into account that the evaluation is performed in a specific research context in which the goal is to compare the usability of these tools by architects during the design process, from a Flemish perspective. As this may not have been the intended purpose during the development of these tools, some criteria are not or insufficiently present, which results in a rather bad score. However, these scores do not intent to prejudice any of the tools; they are only used as an example in this research context.

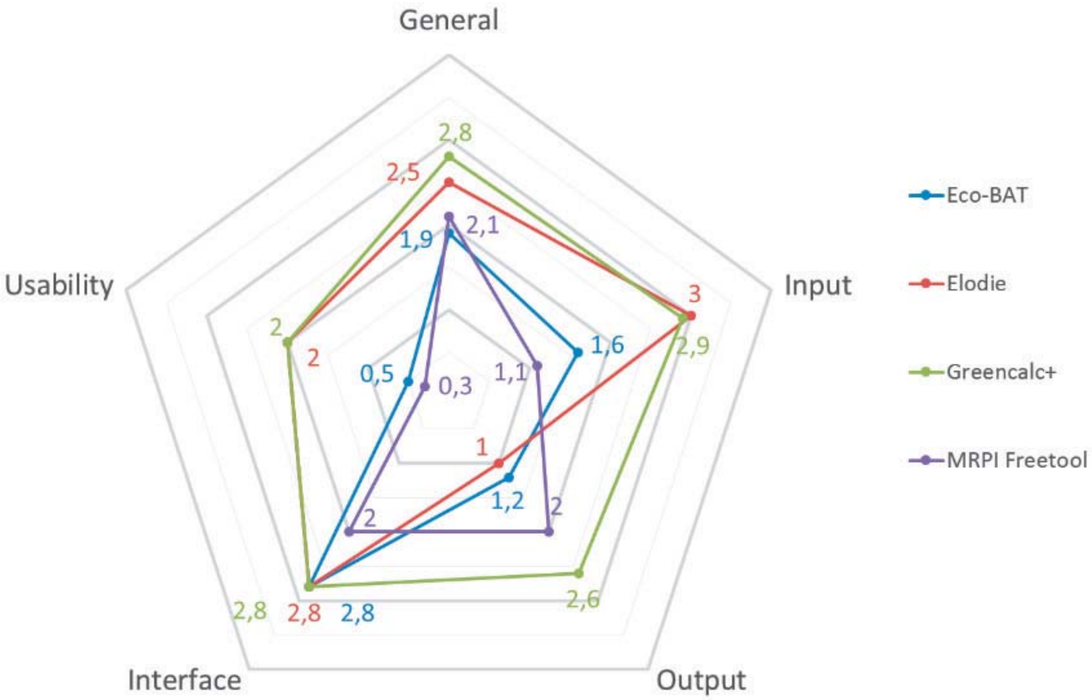

Fig. 2: Final evaluation of the four EIA tools on building level by means of the framework

Table 2: Final evaluation of the degree of architect-friendliness of four EIA tools

	E	EB	G	M
DATA-INPUT	**3.0**	**1.6**	**2.9**	**1.1**
1) Input data				
Limited data-input	3	2	3	1
Quick data-input	3	2	3	2
Default values available (facilitate data-entry)	3	0	3	0
Extensive library/database of standard materials, building components, EPDs, etc.	3	1	3	2
Input consistent with design phase: general (early phases) to detail (final phases)	4	1	3	0
2) Input method				
Simple, intuitive input procedure	3	3	3	3
Input procedure in language of the architect (according to architect's preference)	2	2	2	0
OUTPUT	**1.0**	**1.2**	**2.6**	**2.0**
1) Output data				
Simple but supportive information for design decisions	1	2	3	2
Adapted output for different design phases	1	0	1	0
Output level (according to architect's preference)	1	2	3	3
2) Output format				
Convincing, communicative result representation (according to architect's preference)	2	2	3	3
Benchmark provided	0	0	3	2
INTERFACE	**2.8**	**2.8**	**2.8**	**2.0**
Visual communication of graphical user interface	2	3	2	2
Intuitive and flexible navigation (without constant need for a manual / (online) help function)	2	3	3	2
Clear structuring and construction of the project's design steps in the software	4	2	3	1
Restrained set of options and functions (picking things out of a list, clicking instead of typing)	3	3	3	3
USABILITY IN DESIGN PROCESS	**2.0**	**0.7**	**2.0**	**0.3**
1) Global to detail				
Adapted for use in early design	4	0	4	0
Adaptable to design phases (simple versus extensive calculation)	3	0	3	0
Adaptable default values (customized choices)	3	0	3	0
2) Adaptability & flexibility				
Easy data review / change (without loss of data)	1	1	1	2
Quickly and easily create and test alternatives (parallel within software)	4	2	3	0
Real-time feedback on design decisions / changes	0	0	0	0
3) Comparison & feedback loops				
Allowing intermediate evaluation (calculation in tune with design process)	2	1	2	0
Comparing a number of different design alternatives in detail (parallel within software)	3	2	3	0
Analysis impact of decisions / parameters (uncertainty / sensitivity)	0	0	0	0
Generating alternatives and/or optimizations for problems (materials, elements, …)	0	0	0	0
4) Others				
Results for non-impact related aspects in assessment (e.g. comfort, health, economic costs …)	2	2	3	1
GENERAL TOOL CHARACTERISTICS	**2.5**	**1.9**	**2.8**	**2.1**
Availability / accessibility of the tool	2	2	4	4
Link to energy software	1	1	1	0
Tool adapted to use by architects (user skills, background knowledge, preferences, …)	2	1	3	1
Adequate for different types and (design) phases of buildings (1 tool for different applications)	4	2	3	1
Decision support value of tool application	1	1	3	2
Easy to learn	3	3	4	4
Simplicity (intuitive, easy to use and clearly structured, …)	3	3	3	3
Minimal interruption of the design process / implementation in workflow architect	3	1	3	1
Quick application, minimal time required to operate tool (learning vs. using later on)	2	2	2	2
Short calculation time	3	3	3	3
Transparency of the tool (underlying assumptions, calculation methodologies, …)	2	2	2	2
Interoperability (import/export, …)	3	1	2	0
Adequate for local usage (units, language, regional and time specificity)	3	3	3	4
TOTAL EVALUATION OF THE DEGREE OF ARCHITECT-FRIENDLINESS	**2.3**	**1.6**	**2.6**	**1.5**

Legend: E = Elodie®; EB = Eco-Bat; G = Greencalc⁺; M = MRPI® Freetool. Theme score = average of individual criteria scores within theme; global score = average of five theme scores.

4. Discussion

The global evaluation shows that the overall approach in Greencalc⁺ best meets the (Flemish) architect's wishes and needs, especially for the themes output and usability along the design process (Fig. 2). For the data-input, Elodie® (3.0/4) and Greencalc⁺ (2.9/4) achieved the highest score, which is mostly due to their gradual implementation along the design process (e.g. start from an average building which can be refined). For the output, the desired approach for architects (e.g. a one-number score with options to get more information, a custom-made report per project, …) is not found in the tools evaluated in this paper, even though some aspects were present (e.g. the one-number score in MRPI® Freetool (2.0/4) and Greencalc⁺ (2.6/4)). All user-interfaces are quite easy to navigate, but visual representation of the building and indication of possible problem zones, etc. is missing. Another barrier is that input and output are often presented in different tabs. Therefore, the impact of a design change is not directly clear to the user (no real-time feedback). For the usability along the design process, there still are some possibilities for improvement. Elodie® (2.0/4) and Greencalc⁺ (2.0/4) have the highest score within this theme, even though analysis of the impact of a certain design change and generation of alternatives and optimizations could provide some additional useful information. In general, the tools are easy to learn and freely available on the internet (full or demonstration version).

5. Conclusion

Despite the availability of a large number of LCA-based EIA tools for buildings, the uptake among (Flemish) architects remains limited. In this paper, the degree of architect-friendliness of four existing EIA tools (Elodie®, Eco-Bat, Greencalc⁺ and MRPI® Freetool) is evaluated by means of a framework, based on literature and a large-scale survey among 364 Flemish architects and five semi-structured interviews with Flemish architects. For all tools, there is still room for improvement. The data input requirements should be linked more to the ongoing design phase: from global and limited input with adaptable default values for missing data in early design phases to detailed input data in final design phases. The output should be more adapted to the architect's preferences: a global score for the environmental impact for the whole building rather than scores per impact category. Especially, in the early design phases, a one-number score can already give a good indication of the building performance, whereas in the more detailed design phases, the architect should have the opportunity to deepen the results (per building component, per life cycle phase of the building, etc.). In addition, a one-number score enables architects to compare different solutions within their own design to a reference building or a benchmark. As most architects are mainly visually oriented, the interface should use more visual building representations (2D, 3D drawings). In addition, more interoperability and data import and exchange possibilities (especially with already obliged energy performance calculation tools) could facilitate the usage even further and could help to avoid double input of data. Finally, a clear link between modifications of the input (building design) and changes in the output (impact) should be pursued (real-time feedback) to induce a learning process on sustainable material use. These suggestions could improve the design supportive value and architect-friendliness of EIA tools for building design and increase the EIA tool usage by architects during the design process.

6. Acknowledgements

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Ventilative Cooling Potential

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1. Introduction

Europe's building stocks faces a growth of energy demand for cooling, which contradicts the targets of climate protection. Main drivers are growing comfort expectations, changes in architectural design and effects from climate change and urban heat islands. Last not least Nearly Zero Energy Buildings, with their diminished potential for night cooling via transmission losses, call for increased ventilative night cooling.

Ventilative Cooling subsumes strategies that retract heat from buildings or increase the perception of summer comfort by air change or air movement but without use of energy consuming chillers. Ventilative Cooling offers significant potential over a wide range of building types and climate zones. Typical startegies of Ventilative Cooling are night flush ventilation and comfort ventilation.

Both strategies are widespread elements of traditional architecture, still offering significant potential of reducing the cooling load and increasing summer comfort, but today facing numerous practical obstacles: air tightness, protection from outdoor noise and pollutants, protection from risk of burglary and from storms and driving rain make the easy coice of Ventilative Cooling in fact a challening one.

Overcoming these obstacles of Ventilative Cooling and developing improved strategies and technologies for implementation of Ventilative Cooling into Net Zero Energy Buildings, is the aim of the ongoing Annex 62 Ventilative Cooling witin IEA Tasc Energy Conservation in Buildings and Community Systems EBC, running from 2014 to 2017. [1]

The Annex is led by Prof. Per Heiselberg from Aalborg University, DK. Research teams from European and Overseas contries analyse the challenges and potentials of Ventilative Cooling in todays building context and drive developments towards its forced implementation. The author of the paper in hand takes part in this international joint effort, leading Subtask B - Solutions.

Within the first half of the international research program, the authors have conducted strategic analyses of the potential, obstacles and chances of ventilative Cooling, especially focussed on its implementation in Nearly Zero Energy Buildings, leading to a R&D roadmap of further developments needed. The paper in hand describes this research and presents the outcomes in the form of a SWOT Analysis and a R&D Roadmap Ventilative Cooling. Both results form the basis of ongoing R&D Activities during the remaining period of IEA Annex 62.

Recipients of this paper, namely from ventilation and building construction industry, are warmly invited contacting the authors and considering using the gathered knowledge for own developments.

2. Methodology

The strategic analyses of the potential, distribution, obstacles and chances of ventilative Cooling, especially focussed on its implementation in Nearly Zero Energy Buildings have been substructured in

a) Climatic Potential Analysis of Ventilative Cooling
b) Venilative Cooling Building Database
c) Reality Checks
d) Structured Experts' Interviews

In the following chapters, this four-step-approach is presented in chapters 3 to 6, including both the methodology and the results of the specific approach. Finally, a summarization of results, leading to a R&D roadmap Ventilative Cooling is presented in capter 7.

3. Climatic Potential Analysis of Ventilative Cooling

The theoretical Ventilative Cooling potential has been investigated by means of VCP-Tool, an Excel tool by EURAC, Bolzano, IT, specifically designed for the purpose of Ventiative Cooling potential analysis and having been validated against sophisticated dynamic building enegy modelling [2]. The work has been embedded in the Bachelor Thesis of Mr. Martin E. Ecker under the supervision of the author [3].

Investigations have been carried out for test cases representing all combinations of

a) Usage patterns of both residential and office
b) Nine different locations within Austria, formed by Austria's nine regional capitals.
c) Building physics patterns of NZEBs, Low Energy Buildings and "old" buildings.

The calculations on an hourly basis compare the inside heating and cooling setpoint temperature against the outside temperature increased by the temperature rise which is expected from internal and solar gains. Within this comparison, four different cooling cases are differentiated:

Case 0: Outside temperature T_o is lower than heating balance point temperature $T_{o\text{-}hbp}$. Heating is necessary.
Case 1: Outside temperature T_o is higher than but low enough that ventilative cooling at minimum (hygienical necessary) rate extracts excessive heat.
Case 2: Outside temperature reaches a level where ventilative cooling at extended ventilation rate is both necessary and possible.
Case 3: Outside temperature rises to only 2 degrees lower than inside cooling setpoint temperatur $T_{i\text{-}csp}$, which terminates the chance for Ventilative Cooling.

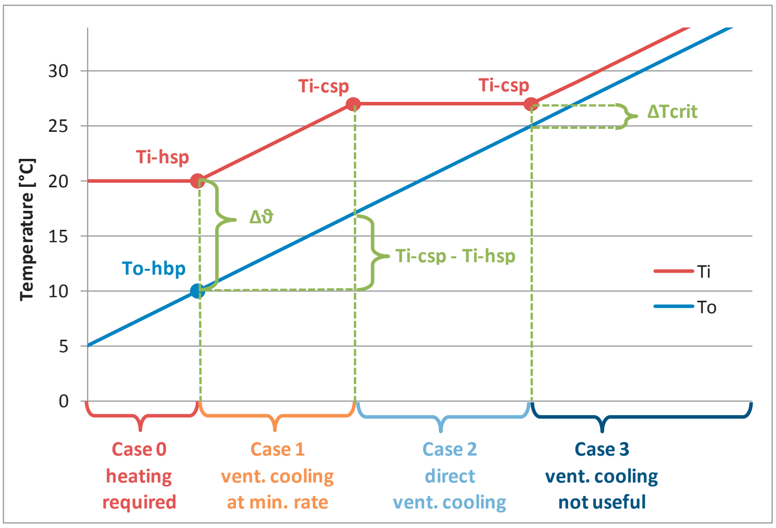


Figure 1: Ventilative cooling cases (with exemplary values on temperature scale)

The heating set point temperature was decided to 20°C, the cooling set point temperature to 27°C operative temperature. Furthermore the benchmark of a maximum acceptable absolute humidity of 13 g/kg, equalling a dewpoint temperature of 17°C, was defined. The calculation results are presented by the following key-figures:

Cooling Case distribution: Relative periods of the full year, when one of the four specific cooling cases occurs. Given in nondimensional proportions of time.

CCP: Climate Cooling Potential per Night. Degree hours between inside cooling setpoint temperarure and outside temperature during one night following a day where Case 3 (Ventilative Cooling not useful) occurs at least for one hour. Counted only if $T_o < T_{i\text{-}csp}$ and if outside humidity is lower than the indoor humidity setpoint. CCP may be averaged for one month or for the full year. Given in the unit of Kh/night.

NCP: Night Time Cooling Potential per night. Specific internal load during one night in exactly the same cases as CCP. NCP may be averaged for one month or for the full year. Given in the unit of $W/(m^2_{floor\ area}.ACH)$

DCP: Direct Cooling Potential per month. Proportion of hours of Cooling Cases 1+2 devided by the hours of a month multiplied by the inner load. Given in the unit of $W/m^2_{floor\ area}$.

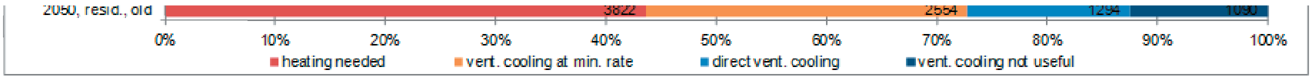
CDH: Cooling Degree Hours per day. Degree hours between inside temperarure and outside temperature within case 1+2. CDH may be averaged for one month or for the full year. Given in the unit of Kh/day.

ODH: Overheating Degree Hours. Degree hours between inside temperature and inside overheating setpoint temperature, which usually is equal to inside cooling setpoint temperature. Summed up over one month or one year. Given in the units of Kh/month or Kh/year.

Active Cooling Avoided: period of cooling case 2 relatively to period of cooling case 2+3. Given in a nondimensional proportion of time.

The parameter study of nine different locations, two different usage patterns (residential and office) plus three different efficiency-standards (old, low-energy-building, nearly-zero-energy-building) clearly shows :

1. There's a substantial Ventilative Cooling potential in Austria, both for office + residential.
2. Climate change will increase the pressure towards active cooling, but will sustain the potential of ventilative cooling.



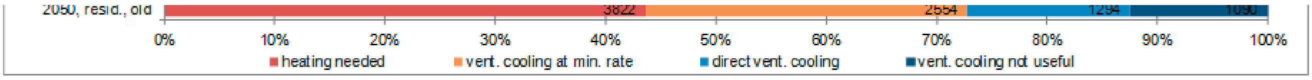


Figure 3 presenting the Cooling Case distributions for the town of Innsbruck.
The light blue beams indicate the number of hours within one year with ventilative cooling applicable and sufficient. The dark blue beams indicate the number of hours with active cooling necessary.

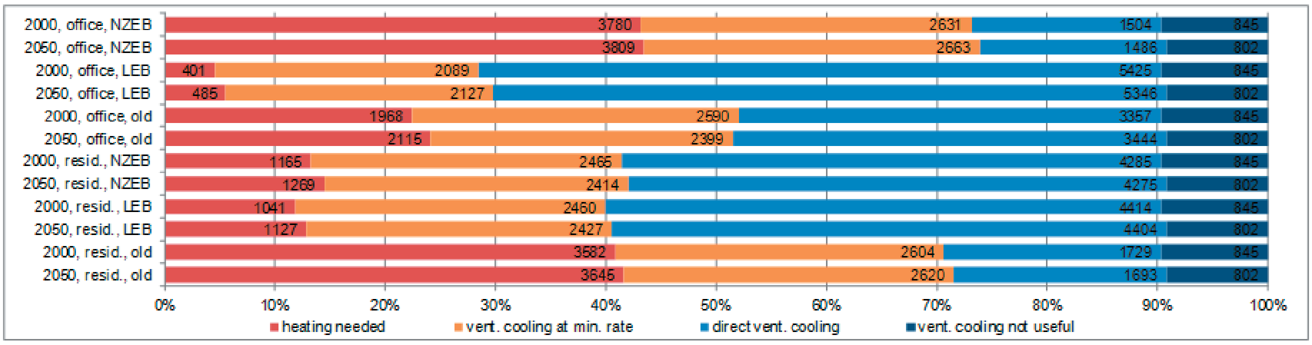


Figure 2: Cooling Case distributions for the town of Vienna

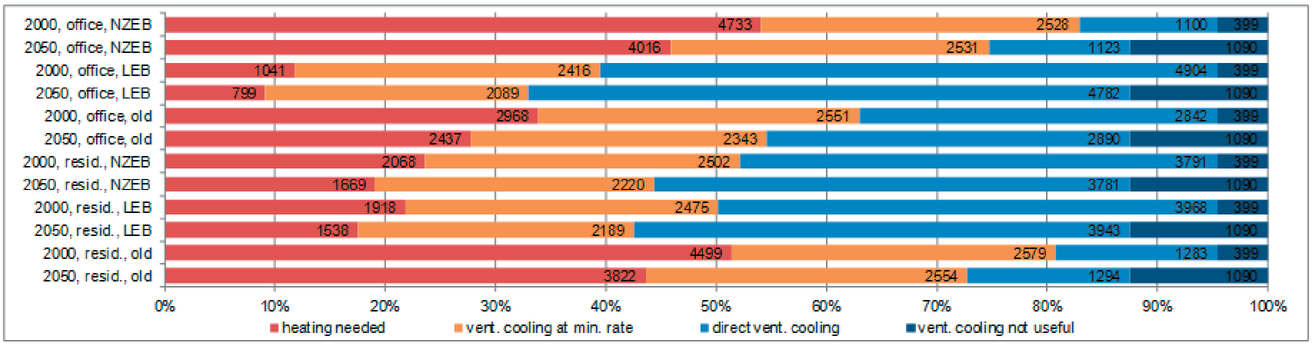


Figure 3: Cooling Case distributions for the town of Innsbruck

The tool does not include effects from thermal mass activation, which practically increase the potential of Ventilative Cooling beyond the results of this parameter study. Thus, the outputs may be regarded as careful benchmarks.

4. Building Database

A building database, has been set up, systematically documenting buildings that deliberately make use of Ventilative Cooling. The database is part of concerted action witin Subtask B of the international programme of Annex 62, supervised by the author [4].

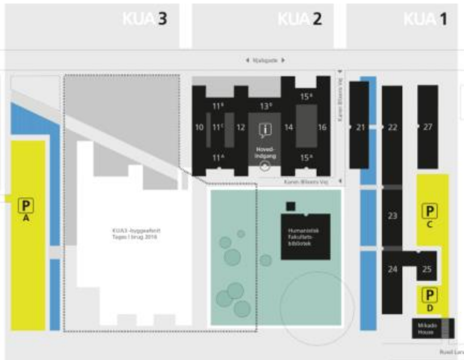
The database contains the following information:

- Statistical building data (dominant use, year of construction, special qualities)
- Political, geographic and climate concerning data (location, climate)
- Ventilative cooling in site design (sun protection, wind guidance, etc.)
- Ventilative cooling in the architectural design (shape, morphology, envelope, etc.)
- Ventilative Cooling technical components and control strategies
  (airflow guiding components, passive cooling components, actuators, sensors etc.)

The database is transposed both as a set of loose-leaf booklet, meant for dissemination, and an Excel spreadsheet, prepared for later statistical correlation analysis.

So far a number of in total 91 buildings from Denmark, Ireland, Austria, Italy and Switzerland are implemented, with the process of filling this database still ongoing. An exemplary piece of the loose-leaf booklet is presented in Figure 4 below.

DK_ Amager_Københavns Universitet (KUA1)

Image 01: East façade	**Image 02:** External solar shading	**Image 03:** Three parts of KUA construction process
		

1. Building Specifications

Address	Karen Blixens Vej 4, 2300 Copenhagen S, Denmark
Building Category	Educational building
Year of Construction	Construction started in 2000 (3 different steps)
Special Qualities	New concepts and strategies for control of natural and hybrid ventilation. User-friendly control
Location	56° northern latitude, 13° eastern longitude, located in urban area. The building complex is surrounded by other same size buildings to the east, west and south and free land to the north. There is a water channel located along the west side of the building complex
Climate	Cfb (warm temperate climate, moist with adequate precipitation in all months and no dry season, warm summer with the warmest month below 22°C)

2.	**Vent. Cooling Site Design Elements** (Solar Site Design and Wind Exposure Design, Evaporative Effects from Plants or Water)
	Evaporative cooling effect of the water channel to the west facilitates the natural cooling effect. The building is sheltered from wind by neighboring buildings
3.	**Vent. Cooling Architectural Design Elements** (Form, Morphology, Envelope, Construction & Material)
	Form: Consists of several long, stretched, rectangular 6 storey buildings placed along north/south direction Morphology: The building is divided in 6 floors, where the first two are intend for teaching, while the 4 last floors are used for offices and research. An atrium, which connects all the different floors, is placed in the middle of each building Envelope: Large windows sections facing east of west, as well as skylights above the atriums on the roof are designed with natural ventilation in mind Construction: Heavy mass building
4.	**Vent. Cooling Technical Components** (Airflow Guiding Components, Airflow Enhancing Components, Passive Cooling Components)
	Natural ventilation is used in rooms for up till 36 persons (offices, group rooms). Mechanical ventilation is used in rooms, which are designed for more than 36 persons (auditoriums, meeting rooms) and in rooms where is required to have mechanical ventilation according to legislation. Around 65% of the floor area is naturally ventilated. Both the inlet and outlet is placed close to the ceiling, and the air is extracted through the chimneys. A mechanical ventilator is located in the top of the chimneys to assist the natural ventilation, when it isn't efficient enough. The group rooms can also be ventilated by manually opening the windows. The offices are ventilated by single sided or cross ventilation principle depending on their location in the building. Night ventilation is done by automated window control making use of the stack-effect. Comfort ventilation is ensured by automatic window ventilation system. Automated awnings are installed on the on the east and west façade windows to provide solar shading.
5.	**Actuators, Sensors and Control Strategies**
	Room sensors for CO_2 and temperature to control the automatic ventilation Users always have the option to overwrite the automatic control. Simple on/off buttons together with an instruction are added to each room The automatically controlled openings and sensors are connected to a CTS-system
6.	**Building Energy Systems** (Heating, Ventilation, Cooling, Electricity)
	District heating, radiators Hybrid ventilation with both mechanical ventilation and automatic natural window ventilation Heating surfaces are added to secure a satisfactory air temperature Information about electricity was not available
7.	**Building Ownership and Building Facility Management Structures**
	Bygningsstyrrelsen is the owner of the building, and Københavns Universitet is the user
8.	**Aknowledgements**
	The buildings are a part of a larger project (3 parts, KUA1, KUA2 and KUA3 – only KUA1 and KUA2 are done). Building description is based on information materials provided by COWI

Figure 4: Exemplary building data sheet of the International Ventilative Cooling building database

It's too early for substantial statistical correlation analysis. More buildings especially from warm climates have to be added. Preliminary results out of the 91 buildings are:

- 60% of the buildings have been found within urban surroundings
- 58% of the buildings use elements of ventilative cooling site design, dominantly wind exposure.
- 79% of the buildings use elements of ventilative cooling architectural design, dominantly envelope and construction+material
- Amongst the airflow guiding ventilation components, which are found in every building, by far dominating are windows, doors and rooflights, followed by dampers, flaps and louvres.

- Amongst the airflow enhancing ventilation components the dominating technology is atria, which is applied in 66% of the buildings. Far behind follow chimneys in 16% and venturi or powerless rotating exhaust ventilators in only 11% of the buildings.
- Additional passive cooling components, such as convective or evaporative or phase change cooling components are applied only in a minority of 30% of the buildings.

5. Reality checks

Reality checks were carried out on two specific buildings, analysing the design process, visiting the buildins, doing spontaneous measurements, talking to the designers and users, learning about their practical observations, learnings and attitudes.

The first building, named “zu haus” which in german means “added building” as well as “home”, is a small, newly built, distinctively simple single family house, being added to an old farm house in a rural surrounding. It is equipped with automated windows, controlled by CO_2, temperature and humidity or – alternatively – manually. Solid brick walls and concrete floor slab serve as buffer mass. Exterior sun shading effectively reduces the heat gains during summer. The design allows bouancy driven airflow over three floors. See [5] for the impressum of the architect.

The house shows very high user satisfaction with the implemented system of Ventilative Cooling. An ongoing monitoring proves the effectiveness of the concept. The insect problem has been solved by mosquito nets, which had to be changed once after the clients’s dog overlooked and damaged one. A noise problem doesn’t occur from outside noise, but has been reported regarding the noise of the window actuators, when operating in the early mornig hours. The burglary risk is addressed by burglary proof fixed louvres in the ground floor and is simply accepted regarding the automated skylights.

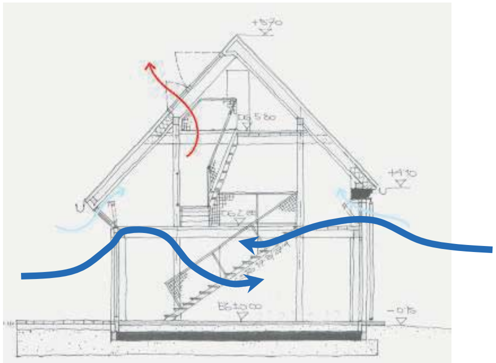


Figure 5: Reality ceck bulding No.1, “zu haus”, Auersthal, Lower Austria

The second building is a newly built office building, again in a rural area, being the headquarters of a wind-turbine operating company. It is a net zero energy building, highly insulated, with cross flow mechanical ventilation with heat recovery and with optimized passive soar gains. The south facing, east-west-sterched atrium serves as an airflow enhancing component for night time ventilation, activating the thermal mass from concrete slabs and walls. Air inlets are constructed as a row of bottom hung façade windows, the outlet vents are powerless rotating tornado vents. Additionally to night ventilation a chiller for humidity control and peak load cooling and a concrete core slab activation via chiller or alternatively via freecooling have been installed. A fully automated centralized DDC-system controls all functions. See [6] for the impressum of the architect.

After its first year of operation the house performs well, offering learnings and options for improvement. Especially the multiple technologies challenge the control system, which subsequently has been optimized from parallel operation to alternative operation of mechanical and natural ventilation system.

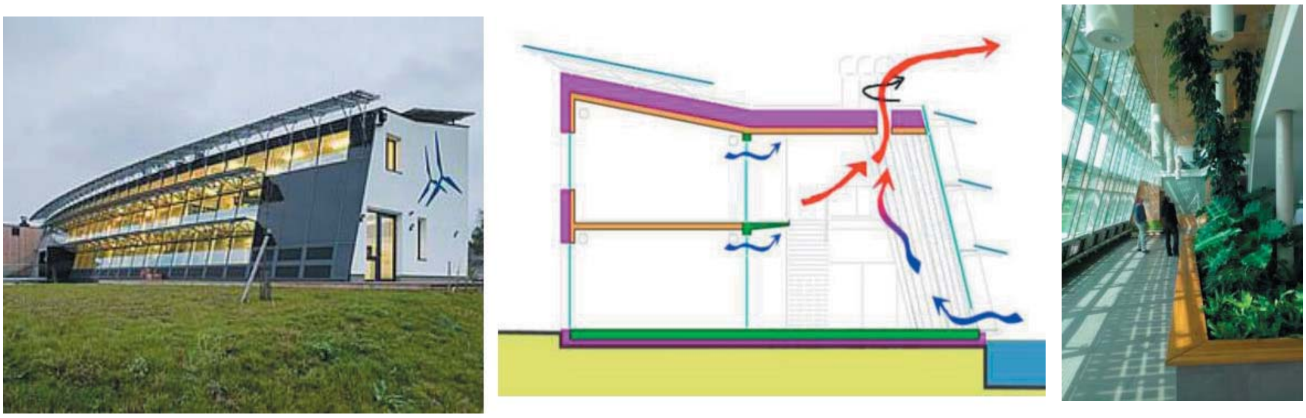


Figure 6: Reality check bulding No.2, “Headquater Windkraft Simonsfeld”, Ernstbrunn, Lower Austria

6. Structured Experts’ Interviews

Additional to the Reality Checks, structured interviews with relevant experts from the fields of architecture, HVAC-design and building-industry have been carried out. Three core questions formed the backbone of these interviews: Do you have personal experience with design and/or opearation of Ventilative Cooling? If yes, which kind of? How do you assess, within or beyond personal experience, the strenths and weaknesses of ventilative cooling? How do you assess the demand for further development in the field of ventilative cooling, to establich ventilative cooling as an competitive alternative to mechanical cooling and air conditioning?

In total eleven interviews have been carried out. The answers showed quite a consistant picture and confirmed the assumptions and observations which had been the drivers for establishing Annex 62 within the R&D network of International Energy Agency. The evaluation of the expert consultations was summarazed in a SWOT analysis, shown in Figure 7 below.

simple	
low maintainance needs	user-dependent
highly economic	limited effectiveness
reliable and robust	influencing architectural design
not compromising the microclimate	sensitive against burglary, insects and pollution
no or low need of auxiliary energy	sensitive agaist noise and driving rain
CO2 and humidity control	raising indoor humidity
STRENGTHS	**WEAKNESSES**
OPTIONS	**THREATS**
Improvement of automation	deficiencies in the design process
optimization of thermal mass activation	miscalculation of effectiveness
harmonizing stand alone components	climate change and urban heat islands
improving wind driven strategies	refusal by clients and users
application towards humidity control	lack of available components

development of basic design guidelines
development of design tools
knowledge deficits

Figure 7: SWOT analysis of ventilative cooling

7. Results: The R&D Roadmap Ventilative Cooling

As an overall result of both the theoretical and practical analyses of Ventilative Cooling potential and challenges the R&D roadmap for the ongoing Task is formulated.

1. Improvement of automation systems, including sensors, actuators and controllers, aiming at better compatibility and at intuitive operability
2. Investigation of strategies towards optimization of thermal mass activation
3. Improvement of wind driven Ventilaiev Cooling strategies.
4. Development of hybrid ventilation and hybrid cooling stretgies.
5. Development of basic design guidelines
6. Development of design tools

Manuacturers are warmly invited to make use of these results and the knowledge gathered and join the Annex 62 with teheir specific product developments.

8. Acknowledgements

The research presented in this paper has been financially supported by the Austrian Ministry for Transport, Innovation and Technologyministries within the Interational Energy Agency's programme. It was carried out together with the Austrian partner in this prramme, e7 Energie Markt Analyse GmbH, Vienna. The Institute of Building Research & Innovation ZT-GmbH particularly wants to express its appreciation to all organisations and persons involved.

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[5] Office building Windkraft Simonsfeld by Architect Wolfgang Reinberg, Vienna

WECOBIS: The Challenge of Planning with Ecological Construction Material

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Summary

To plan and tender ecological construction products still challenges builders and planners and now and then overstrains project manager due to the complexity of the process itself. Finding appropriate construction products comes with questions and causes uncertainties as soon as planners start with first sketches. Comprehensive experience is indispensable, knowledge of product components as well as possible effects on health and environment are mandatory. Even if planners are able to evaluate the various types of information, it is still difficult enough to gather all relevant data and to compare and value the diversely structured product specifications.

Thereafter, barriers in planning phases will follow, e. g. calling for bids along ecological criteria or managing construction work with a sensible eye on the needs for a successful result. This derives partly from multifaceted and contradictory material criteria. As one example, wood as a renewable resource may need chemical treatment in order to resist water or fire damage, depending on the field of application. Because of partly contradictory criteria, planners need to evaluate criteria against each other, in order to figure out the equivalent construction material for the most appropriate solution.

The web portal WECOBIS provides basic knowledge about healthy and ecofriendly construction material. The information system assists with the ecological selection of products and is directed at construction specialists and anyone who is interested in sustainable construction like architects, specialist planners, construction workers and building users or clients.
Since 2015, WECOBIS offers specific text modules that aim at supporting planners in tendering. Within the first development phase until 2015, the text modules focus on products with low emissions for a high indoor air quality standard. Throughout 2016 and 2017, further text modules with additional material criteria will be added.

Keywords: sustainable building, ecological construction material, health and environment

Fig 1: WECOBIS images of construction material

1. Ecological aspects of construction material

Several product qualities became fix standards in planner's everyday life. Products made out of renewable resources, products with minimized impact e. g. global warming or acid rain potential, or products that help to save energy due to their good insulation quality for example, are already approved and confirmed and became a calculable part of planning and construction processes. Parties involved know how to select, plan and construct with them in order to achieve a sustainable as well as economically successful result.
Nevertheless, managing a buildings´ planning and construction phases continuously rises in complexity. The coordination of various specialist fields or high pressure on budget and time schedule do have impact on the processes. Throughout several sub-processes along the value added chain, managing sustainable aspects is often watched as an additional accessory part and its implementation is dragged along the process chain.

In Germany, federal as well as nonfederal initiatives supply builders and planners with data that aim to help with the evaluation, selection or workmanship of ecological construction material. As one example, the federal Assessment System for Sustainable Building (BNB) together with the Guideline for Sustainable Building represent a holistic approach, obtaining construction material in several criteria. Databases with diverse focus on construction material in stock, serve as tools or information platforms for achieving sustainable planning goals, e. g. ÖKOBAUDAT or WECOBIS or e. g. BAUBOOK as a nonfederal database from Austria.
Associations like natureplus or the environmental labels like the Blue Angel aim to highlight products with certain benefit for health and environment, referring on the ISO Norm 14040. For this purpose, they set a portfolio of criteria that must be fulfilled by a product to be labelled. At first sight, this is an easy and simple way for selecting good products within in the opaque market. But on second sight, it is still difficult enough to evaluate certain labels against each other as well as there are further planning criteria which need to be included as well.

Research results and especially well-informed consumer fuel fortification. Gaps and weaknesses in legislation and regulations become more and more visible as the whole theme evolves. Therefore, European and national regulation and legislation gets more extensive with focus on sustainable construction. For example the Construction Products Regulations (CPR) refers on sustainable aspects in basic requirement No. 7 "Sustainable use of natural resources" in the CPR. The requirement No. 3 “Hygiene, health and the environment” aims to avoid the emission of dangerous substances that might cause harm to workers and residents or that might does harm to the environment during a products´ lifecycle.
For further sustainable development, it is indispensable to develop and harmonize regulations. In addition, detailed knowledge of ecological planning strategies and ecological product qualities need to be deepend and distributed. At present, the whole process of selecting, comparing, and planning along ecological aspects is not transparent enough. Therefore it is difficult for non-experts to sort through and sort out relevant or unimportant requirements.

Within this context, this article aims to introduce WECOBIS as a web based information tool which is close-by the need of practitioners. Its database therefore supplies with information and strategy for the selection, comparison and planning with ecological construction material.

2. WECOBIS for material selection & planning

WECOBIS is a web portal providing basic knowledge for healthy and ecofriendly construction. The information is available in German language. Specific information is configured for the German market according to relevant German laws and rules. WECOBIS is part of the planning tools that are used for the implementation of the Guideline for Sustainable Building and its´ application by the Assessment System for Sustainable Building (BNB).
The web page is operated by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) in cooperation with the Bavarian Chamber of Architects (ByAK). Its administrative office has been set up in the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), Division II 6 Construction and Environment.

Users receive comprehensive product-neutral information on components, hazardous emissions within life cycle phases, interactions of different building materials or legal requirements. The contents are applied in practice e.g. with planning & tendering assistance specific to building material; e.g with myWECOBIS as an interface for filing and storing contents of user‘s own projects and e.g with extracted info on classifying building product groups according to BNB requirements.

Herewith, WECOBIS assists with the ecological material selection and is directed at construction specialists and anyone who is interested in sustainable construction: architects, specialist planners, construction workers and building users. Assistance is given in:

- development of material concepts for sustainable planning
- pre-selection of certain product groups based on environmental and health aspects
- classification of building material according to criteria under the Assessment System for Sustainable Building (BNB)
- definition of quality levels in early planning processes with regard to the selection of construction materials
- planning with building materials in overall comprehensive terms across all life cycle phases

WECOBIS planning & tendering assistance

Additional to general information about ecological construction material, the BBSR started to develop specific support for planning and tendering. The comprehensive guideline supports with three different types of information:

- General product group information:
  In the product group task bar, the user can find universal information on tendering as well as references to tendering assistance of other providers. Statutory requirements can also be found there, such as on workplace safety or on threshold values for product emissions.
- General information on planning and tendering:
  This category contains an overview of all relevant aspects of a product during several planning phases. You can find advice on e.g. which ecological material criteria must be decided during certain planning phases or on e.g. which kind of product specification might be valid as confirmation document.
- Text modules on ecological material requirements:
  Main intention was to offer text modules that can be directly used for wording in tender documents. WECOBIS now provides a continuously expanding selection of ecological requirements. That makes it possible to easily describe the ecological quality of a product, regarding its field of application and possible harmful substances.

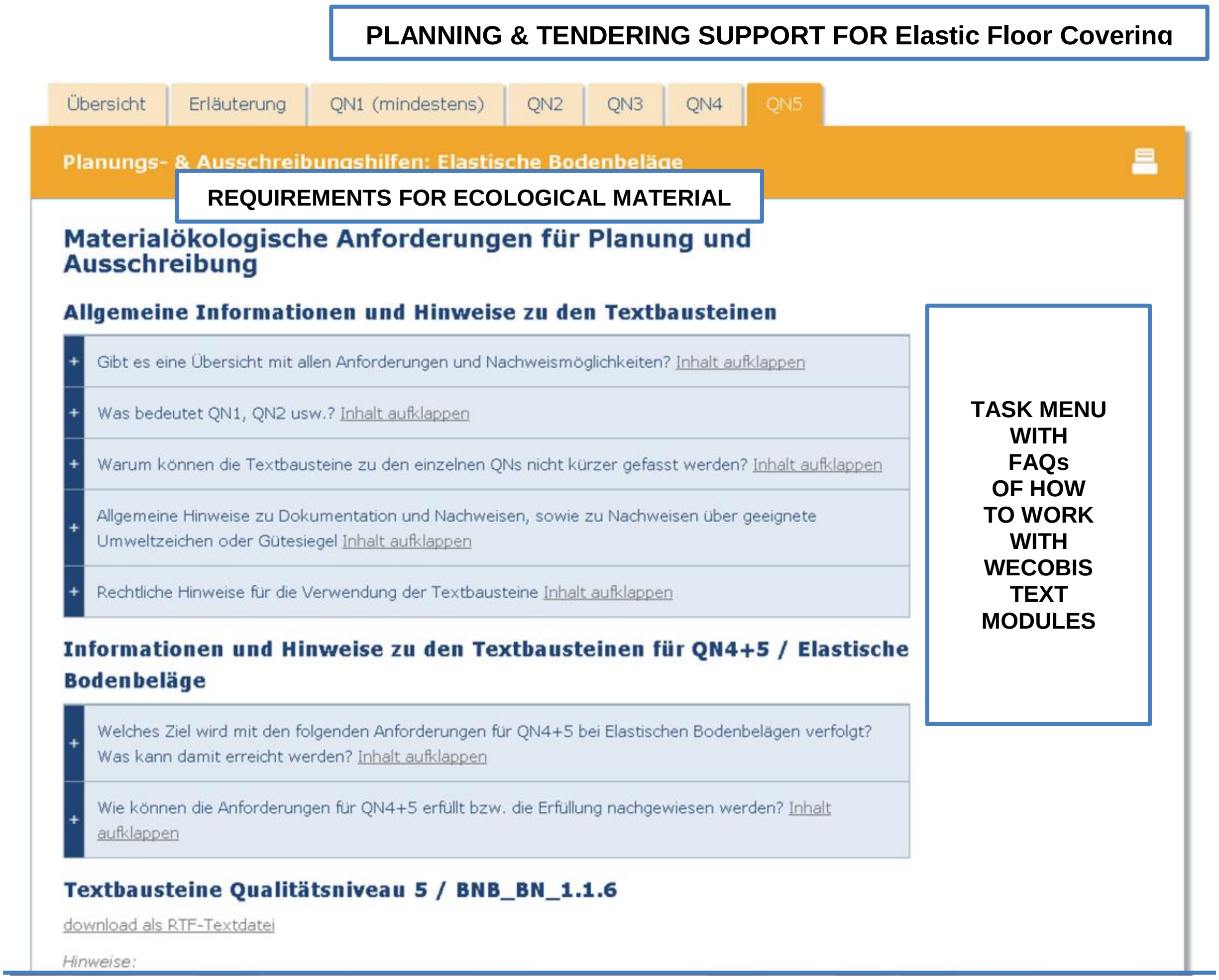
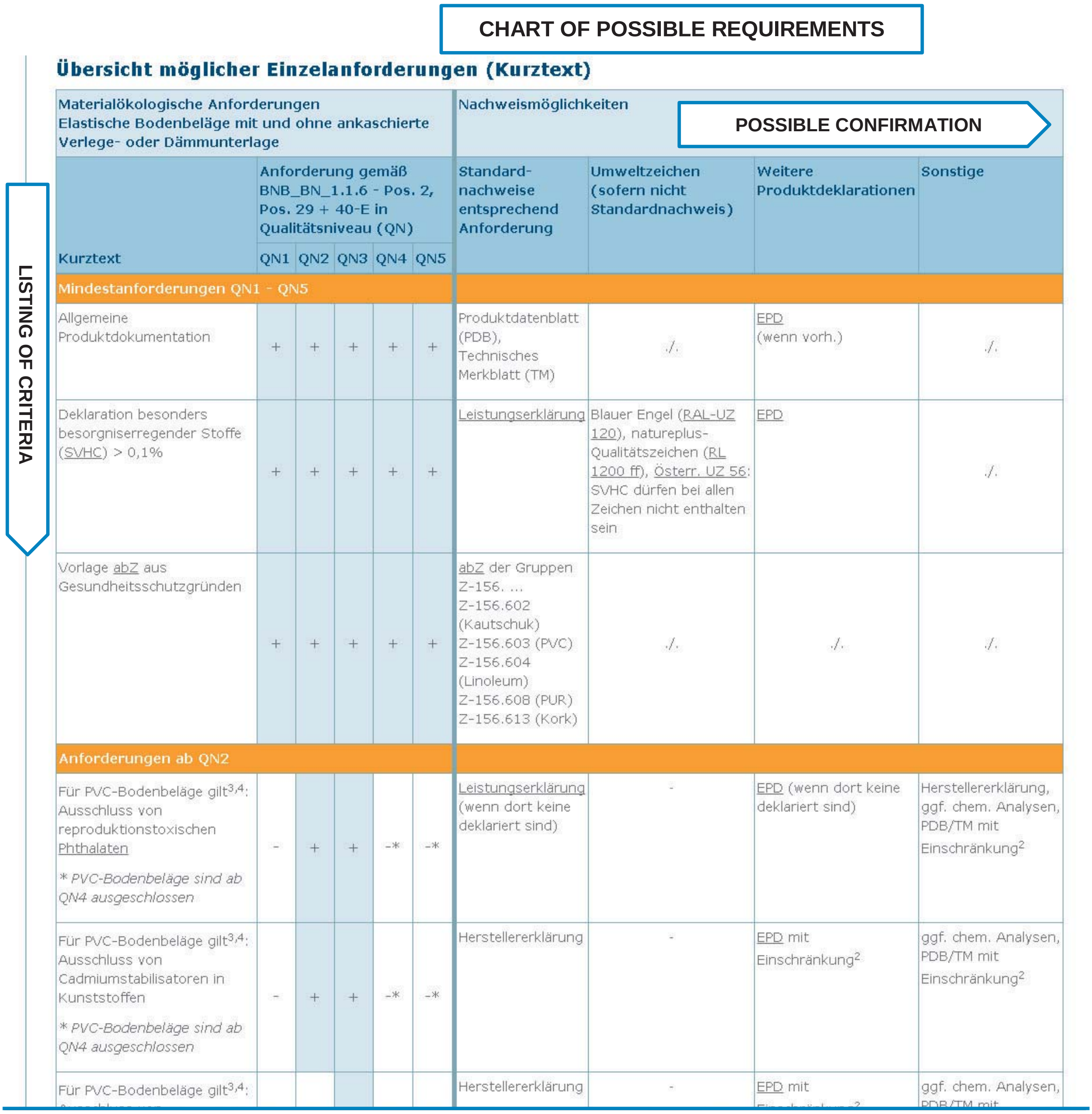


Fig 2: Screenshot of webpage with text modules, source: www.WECOBIS.de

The recently published text modules ground on the BNB Criteria 1.1.6 (Risks for local Environment). It is one of several criteria with relation to construction material within the Assessment System for Sustainable Building (BNB). The text modules help to ensure that substances and

products can be reduced that pose a risk to environmental resources, i.e. groundwater, surface water, soil and air. This includes the timeframe while work is being carried out or while products are exposed to weathering (e.g. washout, leaching, etc.).
All available text modules can be downloaded from WECOBIS. They can be used by just copying them. Planner can use the text modules either next to individual positions within the tender document or as a compendium in the preliminary note or in the appendix.



Übersicht möglicher Einzelanforderungen (Kurztext)

Materialökologische Anforderungen Elastische Bodenbeläge mit und ohne ankaschierte Verlege- oder Dämmunterlage						Nachweismöglichkeiten			
	Anforderung gemäß BNB_BN_1.1.6 - Pos. 2, Pos. 29 + 40-E in Qualitätsniveau (QN)					Standard-nachweise entsprechend Anforderung	Umweltzeichen (sofern nicht Standardnachweis)	Weitere Produktdeklarationen	Sonstige
Kurztext	QN1	QN2	QN3	QN4	QN5				
Mindestanforderungen QN1 - QN5									
Allgemeine Produktdokumentation	+	+	+	+	+	Produktdatenblatt (PDB), Technisches Merkblatt (TM)	./.	EPD (wenn vorh.)	./.
Deklaration besonders besorgniserregender Stoffe (SVHC) > 0,1%	+	+	+	+	+	Leistungserklärung	Blauer Engel (RAL-UZ 120), natureplus-Qualitätszeichen (RL 1200 ff), Österr. UZ 56: SVHC dürfen bei allen Zeichen nicht enthalten sein	EPD	./.
Vorlage abZ aus Gesundheitsschutzgründen	+	+	+	+	+	abZ der Gruppen Z-156. ... Z-156.602 (Kautschuk) Z-156.603 (PVC) Z-156.604 (Linoleum) Z-156.608 (PUR) Z-156.613 (Kork)	./.	./.	./.
Anforderungen ab QN2									
Für PVC-Bodenbeläge gilt[3,4]: Ausschluss von reproduktionstoxischen Phthalaten * *PVC-Bodenbeläge sind ab QN4 ausgeschlossen*	-	+	+	-*	-*	Leistungserklärung (wenn dort keine deklariert sind)	-	EPD (wenn dort keine deklariert sind)	Herstellererklärung, ggf. chem. Analysen, PDB/TM mit Einschränkung[2]
Für PVC-Bodenbeläge gilt[3,4]: Ausschluss von Cadmiumstabilisatoren in Kunststoffen * *PVC-Bodenbeläge sind ab QN4 ausgeschlossen*	-	+	+	-*	-*	Herstellererklärung	-	EPD mit Einschränkung[2]	ggf. chem. Analysen, PDB/TM mit Einschränkung[2]
Für PVC-Bodenbeläge gilt[3,4]:						Herstellererklärung	-	EPD mit	ggf. chem. Analysen,

Fig 3: Screenshot of webpage with overview to text modules, source: www.WECOBIS.de

3. Prospect and further development

Throughout 2016, a team of experts around WECOBIS will develop additional text modules with complementary relevance. The advancement will enlarge the database itself. Relevant construction material themes like BNB Criteria 3.1.3 (Indoor Air Quality) or BNB Criteria 4.1.4 (Dismantling, Waste Separation and Utilization) will find consideration. Parallel, universal help text will be detailed with emphasizes on planning and workmanship requirements. This should give a more practice orientated overview of relevant legislation, sum up of available declarations according to ISO 14400 Type I and should give advice for strategic steps to be taken. Auxiliary content will be gradually uploaded as available throughout 2016 and 2017.

Within the next years, the fast evolving market for ecological construction material will stay characterized by permanent changes e. g. due to the classification and reclassification of chemicals by REACH or due to continuous launch of new or modified products.
More and more, planners and project manager demand integral strategies which support in material selection, evaluation and planning as well as in construction implementation. For this purpose, it might help if databases and tools adapt to each other, if specifications and rules get harmonized and extrapolated along changing market requirements.

The current knowledge gap can be characterized by various questions that need to be discussed and tackled:

- What are necessary criteria of ecological building products?
- How can they be defined and by whom?
- Which ecological aspects or criteria rival each other?
- Which information, tools and methods are missing for supporting a successful product selection, planning and construction process?
- Which special knowledge do planners and experts lack for choreographing ecological construction material throughout the whole process?
- How can know-how be transferred and how can it be set as well-known standard?
- What kind of data, what kind of knowledge, what kind of communication is necessary for organizing and handing over the vast amount of data and knowledge?
- How should interfaces between sub processes be reconfigured?
- How should processes be reorganized and be systematically restructured?

Several questions can be channeled in aligned strategies in order to anchor ecological construction material as a manageable standard. Proceeding standard could help to define individual project goals as well as they could ensure high quality solutions for using ecological construction material as an important part of sustainable building.

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Where do architectural design ideas come from? A sustainability and bioclimatic-oriented teaching experience

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Summary

This paper presents a teaching experience focused on the introduction of methods and tools (site and repertoire analysis, protocols, games, procedures, models, modular design, crits, self, peer and instructor formal and informal evaluations) to enhance the design process of sustainable, bioclimatic-oriented design of school buildings. Results derived from the referred action-research were reflected in students' attitudes towards their engagement in activities and the completion of tasks. Methods and tools proved to be important parts of design pedagogy, as well as sound, step-by-step introduction of theoretical concepts and technical information. Students expressed greater understanding of architectural design, as a process and the incorporation of a large variety of variables (environmental, technical, functional, aesthetic, cultural, psychological), which demand quantitative as well as qualitative decision-making. Sustainable building design, based on bioclimatic architecture needs such concepts at its basis. Students showed increased confidence in their own approaches to design problems, though the challenge of actually incorporating sustainability demands in the core design – instead of mere add-ons – persisted and inspired course advancement.

Keywords: sustainable design; bioclimatic architecture; design teaching; design process; school buildings

1. Introduction

Technological advances and global, social as well as economic changes have directly influenced the design of the built environment, increasing the complexity and functional requirements of buildings (Kowaltowski et al., 2010). In this scenario, a new professional posture is required, capable of a more responsible, sensitive and scientifically sound approach to address environmental impact and human factors among other design demands. The contemporary world's pace demands professionals capable of keeping up with the dynamic production of knowledge and speed in technological advances, as well as obsolescence. This new order impacts the architectural design pedagogy as well. It implies that design students need a deeper understanding of background knowledge and acquire new abilities and attitudes towards the ideas of their proposals. Producing designs that are fresh, creative, and technologically adequate, as well as environmentally correct to the problem domain has become mandatory. Research in the field of design methods is important to assist professionals in their search for solutions able to respond to the contemporary demands. Design methods are concerned with the design process of both students and architecture professionals. They should support the search for the right information to apply in decision-making. In the creative phase they ought to stimulate ideas to solve design problems at hand.

In a previous study, the strength of restrictions imposed on the design solution realm was tested in the teaching studio environment (Kowaltowski et al., 2007). The results of this study showed that restrictions could enhance creativity in students, especially through the challenge of breaking the imposed barriers by adopting new and innovative solutions. In addition, with restrictions made clear, students were more confident in their design proposals as a whole. A later study (Kowaltowski et al., 2010) showed that the application of methods to stimulate creativity could improve student designs.

Especially for bioclimatic design, ideas must be thought through in more detail and based on first principles of the physics involved. Educational enhancement through the use of design methods is therefore important to ensure that the job market gains environmentally conscious professionals, capable of thinking out of box. To address the issues of architectural design education in the current professional world, this paper discusses design methods as support to a design studio where sustainable, bioclimatic architecture of school buildings is taught.

2. Design process and architectural education

To increase design quality and productivity stakes have been put on design methods in the last fifty years, especially in architecture. The primary goal in developing design methods was to diminish subjectivity in design, to apply scientific knowledge more effectively and use information technology productively. The list of tools still used today includes brainstorming, analogy and attribute lists to aid in "removing mental blocks" (Kowaltowski et al., 2006; Kowaltowski et al., 2010). Adding structure to the decision-making activity is considered essential to conduct a productive design process. Understanding this process has been a long-standing quest in the design methods movement. The creative process is considered complex, solving what are termed wicked or ill-structured problems (Rittel & Webber, 1973). Wickedness consists in the continuous redefinition of the problem during the period of its resolution and the impossibility of testing the validity of solutions (Coyne, 2005).

Reasoning proceeds from objective and functional assessment to means or (product) decisions in a design process. This does not follow a formal scientific path in which, by deduction, a logical result is reached. Addressing design as a whole, or of its part, is a further difficulty that experienced designer will usually tackle through the recall of known design solutions and of travelling constantly with eye, mind and hand between the parts and the whole. Thus, design is not a grammatical construction of a sentence, by a combination of parts to form a whole (Snodgrass & Coyne, 2013). To improve the design process therefore, especially for the novice designer, methods are important to stimulate innovative ideas. Techniques such as “Brainstorming”, criticism and decision-making activities should intertwine with traditional design, drafting, prototyping and testing activities, to provide the foundation for greater innovation and awareness in the design process.

Most design education occurs through the studio system. The personalities (instructors) present and their individual ways of approaching design have a great influence on students (Mewburn, 2011). Thus, in many studio situations, the pedagogy applied is not specific, structured or based on principles (Eigbeonan, 2013). Design education should consider engaging students in questioning their pre-suppositions they bring from previous experiences. Students need to expand, and at times, reject responses in the design dialogue of a studio setting (Snodgrass & Coyne, 2013; Danko et al., 2006). Students need to acquire reflective skills. Essential knowledge must include: facts, understanding, skills and familiarity with a subject or concept (Paulsson, 2005).

Viewing design as pure art has often been identified as a problem and this is also a frequent criticism of typical design studio pedagogies. Investigations of professional practices have uncovered that especially architects often lack knowledge of, or fail to anticipate, user needs (Nicol & Pilling, 2000; Salama & O’Reilly, 2002, D’Souza, 2009). In a report, Paulsson (2005) shows that design is too often, unconsciously based on careless and superficial concepts, and design solutions are essentially based on artistic or economic premises.

The synthesis of knowledge coming from multidisciplinary areas continues to be a challenge in the typical design-studio of most architecture schools. Many studies have examined this setting in relation to diverse aspects: learning experiences and styles, efficiency, quality of designs, etc. (Oxman, 1999; Goldschmidt & Tatsa, 2005). Other studies identified problems in architectural education as related to design communication and the introduction and application of computer-aided design in architectural courses (Nicol & Pilling, 2000). Schön (1983) describes design as a reflective conversation with the design situation, thus addressing the human thought-processes and the language (drawings and models) used to make design decisions.

To improve design education, universities - and architecture schools in particular - have made important efforts. New teaching methods are mainly concerned with enriching the pure artistic vision of architecture, through the insertion of scientific knowledge and social responsibility. Environmental comfort and the question of sustainability demand a deeper understanding of technical information and scientific concepts (Bala, 2010; Castaño & Kelly, 2012). Social sciences need to instil sensitivities towards the relation of human behaviour and elements of the built environment. Finally, results of studies on creativity should enrich the design process in the learning environment (Eigbeonan, 2013).

In design education, special attention must be paid to the difficulties of progressing from whole to part and part to whole in a conscious and efficient way, for students to produce designs that have combinatorial qualities. Problem solving needs to be addressed through teaching methods and the introduction of tools. To help students to overcome hurdles in moments of lack of progress, or what is colloquially called “being stuck”, tools are necessary and the rich array of methods to stimulate creativity, available in the literature, should be tested in the design studio. The UIA/UNESCO (2011) charter for architectural education stipulates that a variety of methods should be applied to enrich the design-studio environment culturally and urges flexible teaching to relate to varied demands and design problems. Most design schools have yet to tackle this call.

With increased complexity in the design world, innovation should no longer rely on talent or chance alone. Essential in the architectural design process is the search for new ways of solving problems (functional, technical, social, urban and aesthetic) in intelligent and environmentally responsible ways. The capacity to solve problems depends on two important factors of cognition: repertoire (facts, principles, concepts, examples and experience) and heuristics of problem solving (systemization of insights). Expertise is context specific and it develops over time as a person matures (Cross, 2004). Most outstanding designers also rely on 'first principles' to stimulate design ideas and concepts. These experts explore the problem space, to frame it (Lawson, 2005). In many cases, creative solutions arise when there is a conflict to be resolved (Cross, 2003). Such data shows that research on the design process is rich and design education must find ways to integrate the results of such investigations.

While most design schools have acknowledged the need to educate students to provide sustainable solutions, progress in achieving high performance levels has been limited by a number of aspects, steming from many sources. The lack of vision or awareness is probable the most robust barrier to overcome, as students might be tempted to simply attach technical solutions to a given design, instead of actually incorporating sustainable concepts in the design core from the outcome.

3. The teaching experience and its methodology

This article presents a teaching experience in accordance of a bioclimatic architecture design studio which introduced design methods and tools for students to develop a school building design and develop their own design process. The course is taught in the third year of a six-year night course at the School of Civil Engineering, Architecture and Urban Design of the University of Campinas – Unicamp, in Brazil.

The bioclimatic design-studio was conducted in 2015. The pedagogy applied was based on Archer (1965) and the phase A-S-E (analysis, synthesis and evaluation) as shown in figure 01.

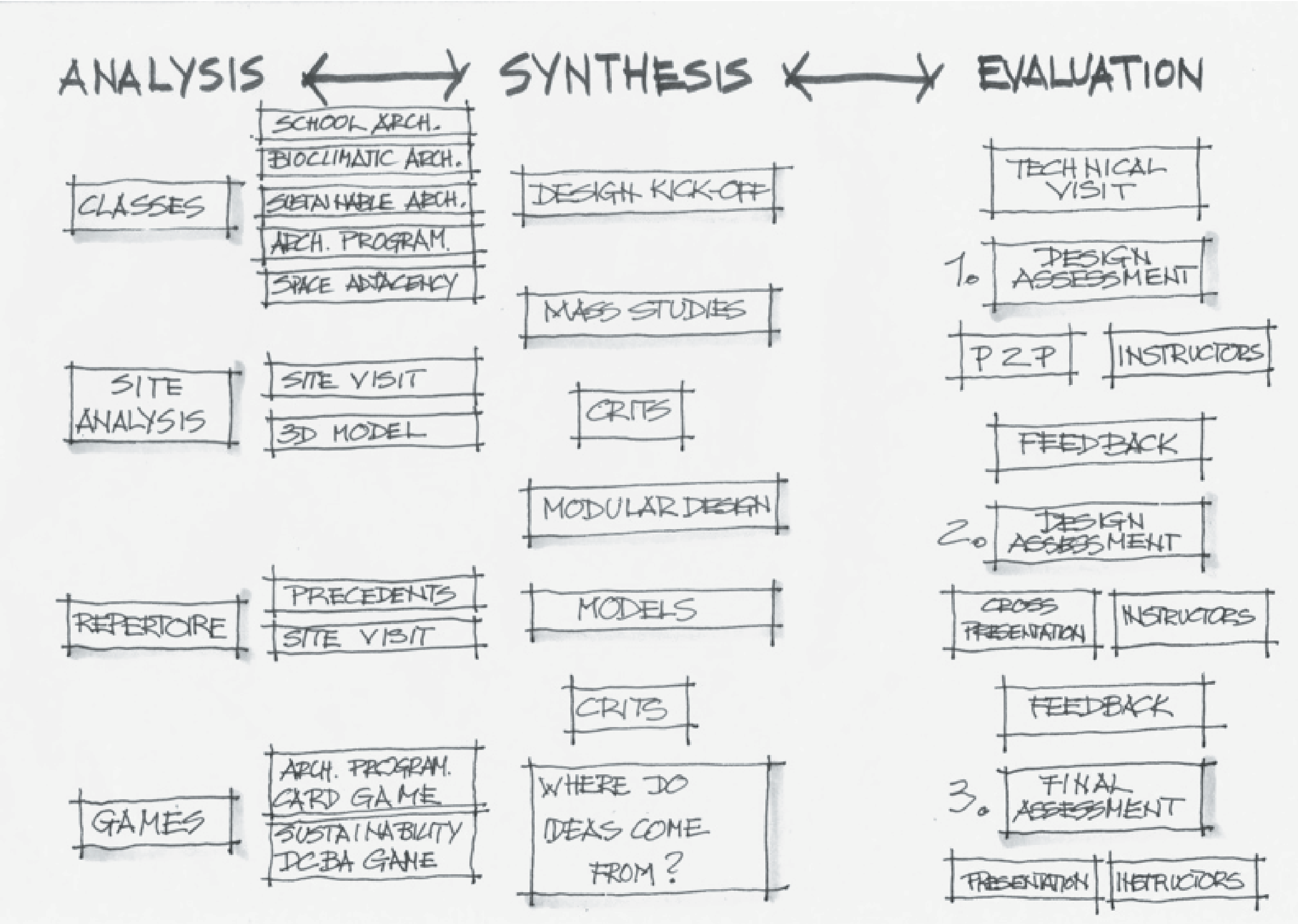

Figure 01: Methods and tools applied in the bioclimatic school design studio

3.1 Analysis

The first phase of a design process is analytical. Information is gathered and organized to support the solution search and decision-making. For novice designers this phase is not only important to understand the design problem at hand but to gain knowledge on the architectural typology, in this case was a school buildings, and on bioclimatic and sustainable architecture. Tools were made available to students to learn procedures to evaluate the building site and to develop an architectural program. Theoretical classes were included in this design studio consisting of classes on: Thermal comfort; Bioclimatic Architecture; Sustainable Architecture; School Architecture; Architectural programming; Space adjacency analysis.

Site analysis followed. The site analysis was prepared by pairs of students, and presented as a small poster and a 3D physical model. The site chosen for the development of a bioclimatic school design is reserved for a school in the zoning plan of Campinas. The neighbourhood selected has the characteristics of typical outlying urban areas of Brazilian cities. Students were asked to analyse the site and its surroundings following a list of specific aspects.

Repertoire analysis was required. Students were asked to choose and analyse seminal school design projects. The analysis included data and a critique of a list of specific aspects. A Technical visit was included. Students visited a school building recently built on part of the chosen site. This school building follows the requirements of FDE (Fundação para o Desenvolvimento da Educação do Estado de São Paulo), the agency in charge of building and maintaining school buildings run by the State of São Paulo.

Finally, card games were introduced. An architectural programming game helped students develop their own school design brief. A sustainability game based on an adaptation of the Dutch DCBA approach aimed at reinforcing concepts and at helping students to define environmental goals for their proposals. Performance targets were collectively agreed upon after the completion of the second game.

3.2 Synthesis

Design kick-off and mass studies exercises got the design process started. Even though students have all the essential material at hand, to generate the first design proposal ideas, they will often embark on not the most productive paths. To avoid such, mostly frustrating, efforts the teaching experience introduced a design kick-off method. Figure 02 shows scenes of this activity and some examples of first ideas based on a short list of specific design criteria of each pair of students, a 2D model of the site, a modular grid and 2D space blocks representing the synthesised architectural program.

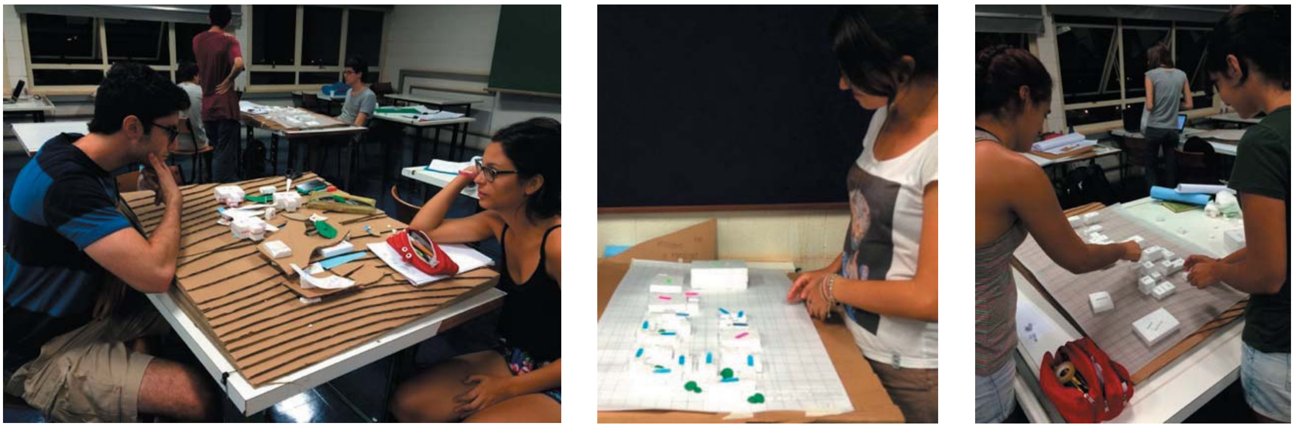

Figure 02: Design Kick-Off activity and examples of first Mass Studies

Modular Design and Models were two important design tools used throughout this exercise. Students were asked to have their 3D models always at hand during class to confer design decisions and carve out new ideas for analysis.

Architectural volumetric integration is a design problem they encountered for the first time. The difficulties of creating logical plateaus for siting needed to be worked on. Also, for school projects the designer must solve the problem of relating large volumes, like the gymnasium to fragmented buildings for classrooms, for instance. 3D models were coupled to modular design. FDE school buildings are based on a classroom size module, as a result of the use of prefabricated construction elements. Students were given a short explanation on modular design during the School Architecture class and the concept and its advantages were reinforced during crits. This concept was also part of the Kick-Off exercise to give students a sense of scale of the design problem at hand.

After the second hand-in, as outlined in the schematic representation of this design class in Figure 01, a special feedback session was introduced, called "*Where do architectural design ideas come from?".* This activity was important to focus on the design process and give students a clearer view of how design development can move forward. Part of the content and structure of this session is outlined in Figure 03.

Bringing all design problems (plateau definitions, relation of large and small volumes, opening orientation, impact of pedagogy on building layout, structural considerations, coherent building and roof form, single or double loaded corridors and impact on ventilation) together and solving each of them iteractively until a satisfactory final synthesis is achieved is the greatest challenge in a design process. Creative ideas often arise from restrictions or challenges. Each one of these elements needs constant evaluation during the design process.

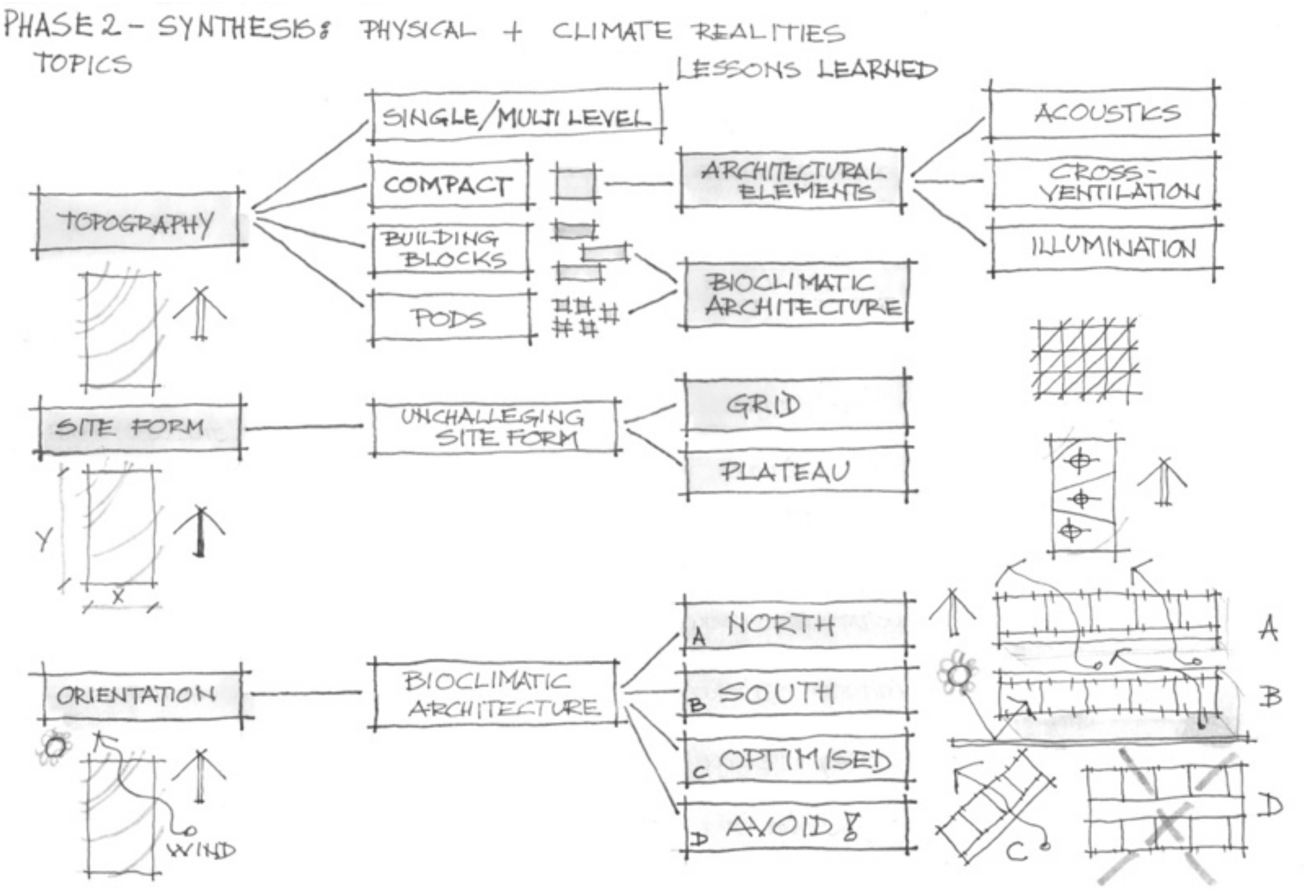

Figure 03: Part of the Design Synthesis: Where do architectural design ideas come from?

3.3 Crits and evaluations

Three design assessments occurred, when each group of students presented their designs with printed material and physical 3D models. The schematic representation of this teaching experience, shown in Figure 01, outlines the logistics of assessments.

All evaluations used an assessment sheet. Each topic had clearly defined criteria for grade levels. Instructors and students, when asked to evaluate proposals of classmates, used the same grading sheet. The evaluation topics were: Presentation (quality and clarity of design communication); Technical drawing information; Site planning and urban integration; Architectural quality (form, volumetric proposition, language); Programming adequacy (school, pedagogy); Functions and dimensional adequacy; Thermal comfort (bioclimatic design with attention also to natural lighting and acoustic interference of functions); Wayfinding and accessibility; Sustainability; Structural logic, construction materials and technique; and finally Design Process.

Figure 04 shows the final presentation of the students' work and evaluation of instructors. The final design documentation included typical design proposal drawings (plans, sections, evaluations, perspectives, details), a physical model and a detailed justification of design decisions in relation to bioclimatic principals, sustainable building design, school pedagogy adopted.

Figure 04: Examples of final student group design proposals

4. Discussion and conclusion

This article presented a teaching experience, which combined sustainable/bioclimatic architecture, school building design and design methodology. The main emphasis of the design studio was on making students aware of their own design process development and base decisions on justified design ideas. In the design studio setting, students were stimulated to learn to reflect and analyse step by step their decisions. Each pair of students was stimulated to externalize such reflective analysis through design conversations, sketches, crits and more formal evaluations, as such events may then demonstrate more clearly where design ideas came from, why certain decisions were made and explain the logic that governed the design process and the path that it followed.

The several methods and tools (site and repertoire analysis, protocols, games, procedures, models, modular design, crits, self, peer and instructor formal and informal evaluations) introduced to students proved to be important parts of design pedagogy, as well as formal introduction of theoretical concepts and technical information. Sustainable building design, based on bioclimatic architecture, needs such concepts at its basis. The special feedback session gave a clearer view of how design development can move forward. Experimentation was increased through the development of several options which were then analysed and lessons were learned.

Positive results were reflected in greater engagement in activities and completion of tasks. Students expressed better understanding of architectural design as a process and the incorporation of a large variety of variables (environmental, technical, functional, aesthetic, cultural, psychological), which demand quantitative as well as qualitative decision-making. Thought students also showed increased confidence in their own approaches to design problems, the challenge of actually incorporating sustainability demands in the design core was not completely overcome. The detailed description of this teaching experience is underway to open the procedures to criticism and refine the steps, tools and methods adopted.

5. Acknowledgements

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SBE16 Hamburg

Full Paper of Special Sessions

PLANNING FOR ENERGY EFFICIENT CITIES – How to achieve the sustainable Energy Smart City - The PLEEC Final Conference -

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Summary

More than 50% of all people globally are living in cities today (UN 2015). Enhancing sustainability and efficiency of urban energy systems is thus of high priority for global sustainable development. This abstract focuses on technological, innovative, behavioral and structural capacities of European medium-sized cities in their transition towards Energy Smart Cities analyzing the variation of strengths and weakness in capabilities in the cities as well as practices and tools for enhancing energy efficient performance of urban energy systems. The findings are based on work done within the EU-FP7 project PLEEC (‘Planning for Energy Efficient Cities’).

Key words: energy efficiency, sustainable urban planning, smart city, technology, behavior

The PLEEC project

The PLEEC project is a three-year project funded by the 7th Framework Programme of the European Commission - led by Eskilstuna Energy and Environment in Sweden. The project started in April 2013 and terminates in March 2016.

The general aim of the project is to make European cities more energy efficient. Therefore PLEEC uses an integrative approach to achieve the sustainable, energy-efficient, smart city. By connecting scientific excellence and innovative enterprises in the energy sector with ambitious and well-organized cities, the project aims to reduce energy use in Europe in the near future, contributing to the EU's 20-20-20 targets.

The main project outcome are six individual Energy Efficiency Action Plans for the six “PLEEC cities” on how to improve their energy efficiency in a strategic and holistic way. In order to make this knowledge available to further European cities the project developed a general model on energy efficiency and sustainable urban planning - accessible through an online model website.

The core objectives of the PLEEC project are:

- To assess the energy-saving solutions and potentials for a comprehensive city planning
- To demonstrate how integrative planning is more efficient than separate measures
- To develop a synergized model for energy efficiency planning considering city key aspects
- To create Action Plans to be presented to decision-makers in the cities
- To identify the future research agenda on the issue of energy-smart cities.

To achieve these objectives, the project methods included gathering information from the six partner cities through analysis of energy relevant indicators, stakeholder engagement and an intense dialogue and collaboration with the city partners.

The consortium consists of 18 partners from 13 different European countries representing six medium-sized cities (Eskilstuna/Sweden, Tartu/Estonia, Turku/Finland, Jyväskylä/Finland, Santiago de Compostela/Spain and Stoke-on-Trent/UK), nine universities (Mälardalen University, Turku University of Applied Sciences, Hamburg University of Applied Sciences, Vienna University of Technology, University of Copenhagen, Delft University of Technology, University of Rousse, Santiago de Compostela University and University of Ljubljana) and three industry partners (Siemens, Smart Technologies Association SMARTTA, Eskilstuna Energy and Environment).

Place-based approach and organizational learning processes

The PLEEC project follows a place-based approach to enforce endogenous urban development by considering local conditions (Giffinger et al. 2014). By supporting a forward-looking and evidence-based strategic planning approach, cities have identified their strengths and potentials. Five key fields of urban development have been identified in which energy efficiency is supposed to become important: (1) Green buildings and settlement structure, (2) Mobility and Transport, (3) Technical infrastructure, (4) Production and Consumption and (5) Energy Supply (Giffinger et al. 2014). The multidimensional description of the most relevant assets and deficits of cities through factors and indicators, respectively the identification of comparable and typical profiles, helps to select other cities for learning and transferring relevant strategies. City profiles provided impulses for further discussion and research; in particular, the identified deficits and assets have been discussed and assessed by local stakeholders.

Capable and sustainable urban energy systems

A technological capability is a capability to achieve outcomes based on technical equipment, methods, competencies and systems, while innovation capabilities refer to abilities and practices to improve performance capacities and capabilities continuously, technological as well as organizational and social. The outcome in this case is efficiency in producing and using basic energy related services in a city (heating/cooling, transportation, recycling and waste management, light, power etc.) which achieve core outcomes of a sustainable city energy system; low cost and resource use of different services rendered including both per unit service and total use in service production (thus also including decreasing service use necessary), low fossil use and use of other nonrenewable resources, low climate gas emission and other material leakages and pollutants. The outcomes should also be performed in an integrated way, based on a capability for synergistic production and use which additionally enhance efficiency. The aim of energy efficiency should be seen in the perspective of a transition to a fully sustainable city energy system, where different measures for improvements in capabilities and performances are steps in such a sustainability transition. Technological capabilities need to be coordinated with behavioral and structural abilities in energy efficiency improvements as these are embedded in improved practices, e.g. of building and using houses in a sustainable way where technological, behavioral and structural factors are integrated as different dimensions. Energy efficiency is also significantly affected by different city conditions of a structural character. A dispersed city structure tends to require more transportation and is less favorable in efficiency terms for public transportation. It also tends to lead to more distributed heating solutions rather than based on common infrastructural solutions like district heating which can increase efficiency based on economies of scale.

Structural aspects of urban energy consumption

There are many measures in spatial planning to improve energy efficiency in cities, as a review done in the PLEEC project summarizes – reaching from climate-optimized urban design, mixed and compact urban development to planning measures supporting small-scale energy production (Meijers et al. 2015). However, these measures must not be seen in isolation, and potential counteracting trends have to be considered. E.g. efficiency gains through improved heating in housing can be outpaced by the increase of floor area per capita (EEA 2010), and while, e.g. in Denmark, average km driven per car are decreasing in urban areas, the number of cars is increasing in the same time. These are partially rebound effects (Fertner & Große, 2016) where the efficiency gains by improving one system are out-balanced by the use of these (energy in our case) in another system.

Urban structure is framing energy use and a city's possibilities for the implementation of measures. This includes the legal system, cultural differences or behavioral preferences. The physical and functional structure of a city, and the region it is located in, influences transport and commuting patterns. Also the coverage of the municipal territory is crucial, giving cities very different possibilities (and limitations) to influence aspects of urban structure. A major question is therefore the scope of e.g. a municipal energy action plan (Fertner et al. 2015). The most efficient actions can be achieved in the municipal concern (e.g. targeted towards the municipal heating system). However, if we aim at long term sustainable development, we have to work with citizens` direct and indirect energy consumption. Cities like Jyväskylä or Turku aim at this broader perspective with their 'one planet living' approach.

Behaviour change as a driver of energy saving

Energy smart cities start with behaviour change of both individuals and organisations. Urban systems, however, are complex and human behaviour even more so. Behaviour is very much context-driven and subject to a multitude of situational and structural drivers. Understanding how people make choices on their energy consumption – whether consciously or unconsciously – is therefore essential for designing energy saving policies in cities as well. More often than not, however, these efforts on city level have not been planned strategically but are rather sporadic, scattered and often lacking in long term effectiveness.

There is a growing body of evidence on the potential of behavioural interventions on promoting energy efficiency. Naturally both technological interventions and urban infrastructure play a crucial role in facilitating – or hindering – energy saving measures of the behavioural kind. However, there is evidence that technological interventions alone have rather low impact without any accompanying plan to promote behaviour change (EEA 2013, 9). This does work the other way too – no matter how well planned and realized a behavioural campaign is, it might not achieve its goals if the energy infrastructure does not permit changing one's behavioural patterns. In an ideal situation in any city, behaviour, structures and technology complement each other.

PLEEC set out to find Best Available Practices to promote behaviour change in the context of energy efficiency in European cities. As all cities possess their own unique combination of technological solutions and planning practices to promote energy efficiency, the behavioural drivers also vary. However, coherence and consistency in the design and use of policy instruments is crucial. Moreover, the power of social influence should not be underestimated – we do care about what our neighbours or colleagues think and do. Providing people with proper information is essential: Messages need to be framed right, their context and timing carefully considered – they need to be meaningful, engaging, encouraging and personalized. Building upon the positive instead of preaching, making energy saving a habit and paying attention to possible rebound effects will set the process in motion. Also acknowledging various barriers to energy saving may help overcome them with different measures, such as incentives or improved information (Kunnasvirta et al. 2015).

Learning and integrating

During the project, several mutual learning procedures have been integrated into the PLEEC methodology to promote sustainable planning for energy efficiency, e.g. cities – cities (study visits, local dialogue forums, opponent groups), researchers – cities (workshops, skype meetings) as well as experts – cities (city groups). However, the (challenging) integration of technology, structures and behaviour seems to be crucial for a sustainable transition into a more energy efficient smart city.

All results of the project are available at www.pleecproject.eu

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EPD and use of external data for building calculation in Denmark

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Summary

A central aspect in quantifying the sustainability of construction works is calculating the life cycle impacts on the environment. Calculating the buildings environmental profile enables the designer to choose e.g. building design, materials, product design alternatives and even specific manufacturers from environmental considerations and thus design buildings that causes less stress on the environment. However, in order to achieve this, the designer has to have lots and various products to choose from with credible and transparent datasets available in easy-to-use calculation tools.

In 2012, Danish Technological Institute initiated the development of a Danish environmental declaration programme for construction products – EPD Danmark. The same year the first Danish version of the private German sustainability assessment scheme DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen) was launched, and by the end of 2014 the Danish government launched a political strategy for the building and construction sector dealing with sustainability.

Related to one of the initiatives in the governmental political strategy, the Danish Energy Agency developed a publicly available LCA calculation tool for buildings. The DGNB system also contains a tool for calculating building LCA, and even though this was developed within the scope of certification, the two progammes are quite similar despite the minor discrepancies.

An important datainput into these calculations are product level life cycle assessment data developed according to the requirements in the European standard for environmental product declarations (EPD). Since there was, and still are, a very limited access to Danish EPD data, both of the tools are based on product and material data from the German Ökobaudat database. This was at the time deemed the most representative alternative in relation to Danish conditions. The LCA data are integrated in desktop versions of the software, which also means, that new EPD data, which are being published regularly, will not be available for calculation, unless updated versions of the programmes are developed and then distributed again.

Using external data does in addition introduce certain limitations to the accuracy and representativity of the calculations. Because almost all available datasets are based on German product manufacturing processes, there will be inconsistencies in e.g. material composition, energymixes, waste treatment scenarios, transport distances etc. in relation to Danish conditions.

Since no national database exists in Denmank, and because it is better to make it right the first time, it was decided to join the European InData collaboration, which is building on already functioning tools and principles. The goal is to build a European LCA data network linking EPD providers, databases and LCA calculation tools on a European scale. This will make LCA data exchange easy and make more product specific data available, thus strengthening building LCA calculations and the dissemination of sustainable buildings.

European LCA data network – open public online database and data format of ÖKOBAUDAT as a starting point?

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Summary

An international open LCA data network structure with a common standard data format is presented, which allows open access to EPD (environmental product declaration) data from all participating databases. There already has been developed an infrastructure for an online database situation with tools and interfaces for data exchange. This system, as established within the German Assessment System for Sustainable Building (BNB) for Federal Buildings, which is following European and International Standards, offers a good starting point for the establishment of an open international data network for LCA databases.

Keywords: life cycle assessment (LCA), sustainable buildings, data exchange, building assessment system, building products, environmental product

1. Introduction

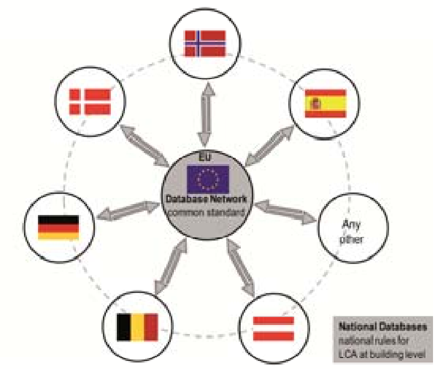

Fig. 1 Scheme – open international LCA database network for sustainable building

LCA is a central instrument to calculate the ecological impact of a building. Currently, in many European or other states a rising number of EPD is produced conform to EN 15804. As products are used within the European or global market, there is an interest to use data from any other EPD program operator, for LCA at building level. To avoid the development of a great variety of databases with the danger of incompatibility of data, the idea is the initiation of an open

International LCA data network structure for sustainable building with a common standard for the data format (Fig. 1).

2. Methodology

A suitable LCA infrastructure has been established in Germany within BNB. EPD data are imported in a database (ÖKOBAUDAT), which is subsequently used by LCA tools at building level (“eLCA”) and contributes to final evaluation. All used programs and tools are open source and publicly available. This supports the idea of an open and transparent exchange of data. These structures are a good basis for joint international activities for the following reasons: the data format is compatible with EN 15804 as well as ILCD format; multi-language support is built in; open source and systematic of underlying soda4LCA allow for further development and adaptions required for an open network with many stakeholders; suitable interfaces allow online data import and export to other tools and systems. Currently within Germany both ways of data import (direct or indirect using open source tool “openLCA”) are used by EPD program operators or other data providers. Considering international co-operations EPD data from Austrian program operator are imported in ÖKOBAUDAT. A database link between ÖKOBAUDAT and Spanish opendap is planned. Denmark is using the data of ÖKOBAUDAT. These activities show potential and practicability of the idea, which is proved by the strong interest of other states in further joint activities.

3. Results and Conclusion

The idea of an open data network would support European ideas and lead the way to a harmonisatin of LCA calculations and evaluation in the building sectors. The challenge is, to get started with joint activities and to develop concepts which meet the demands of various stakeholders. A common standard for data and information will have to be found which still allows for additional national information. The overall goal of a harmonisation and a sensible use of data will require a high transparency of data and background information, also, the determination of different level of data quality. Furthermore, a common basis regarding the technical framework is required, e.g. software, interfaces, hosting.

Implementing European harmonised EPD

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Summary

The European standard EN 15804:2012+A1:2013 [1] for EPD in construction was first publicly available in 2011, it was amended in 2013 and today almost all European Program Operators (PO) have committed to apply the standard. Alone in Germany > 2000 datasets are publicly available for construction products. However, as expected, the practical implementation is still struggling. European Program operators founded the Eco-platform (www. eco-platform.org) in order to overcome difficulties in a concerted way. The first step is achieving a high common quality of EPD, by common verification procedures and qualifications. Next step will be the common applicability for sustainable construction, e.g. for national databases and building rating tools. The added value of EPD under the eco-platform framework is the possibility to use these declarations in all European and international markets. Manufacturers providing Eco-platform EPDs to their customers will be able to optimise their investments avoiding additional fees, work repetition and reducing communication efforts.

Keywords: EPD, European harmonisation, construction products.

1. Introduction

The European standard EN 15804:2012+A1:2013 for EPD in construction was first publicly available as final draft in 2011, it was amended by specifying characterisation factors for LCIA in 2013 and today almost all program operators (POs) have committed to apply the standard.
In 2011 the eco-platform (www.eco-platform.org), an association of established and evolving EPD POs in Europe had its kick off. The objective of eco-platform is to support the implementation of European harmonised EPD, i.e the development of verified environmental information of construction products through EPD according to the horizontal core PCR for EPD of construction products, EN 15804.

2. European Harmonisation in practice

The main achievement of the Eco-platform until today, next to providing a platform of exchange for its members, is providing a common verification procedure for all members. The compliance with this procedure is audited. So far 9 of 14 members have passed the audit and have published ca. 180 so called “ECO EPD” These EPD are accepted and further distributed by all member POs in

Europe. The EPD serve mainly for communicating the environmental performance of products by the respective manufacturers. In some of the existing building certification schemes EPD based data is applied for assessing the environmental performance of buildings: DGNB, BNB in Germany, HQE in France BREEAM in UK and other EU member states. LEED in USA also gives credits for providing information via EPD, Baubook in Austria

The application of the EPD information is still impeded by some technical hurdles. One is the diverging interpretation of EN 15804 by different POs. To support a uniform interpretation and also to support the PCR development for product TCs CEN TC 350 publishes a set of questions and answers (Q&A file) on its website. These refer to a set of issues as allocation, end-of-life system boundaries etc.

The explicit background to the Q&A file is given in a guidance document as technical report, WI 350020:2015, which is still in work, but can be expected in early 2016. It also includes guidance on the calculation and documentation of biogenic carbon. In detail this was also worked out by the product standard EN 16485:2014 “Round and sawn timber - Environmental Product Declarations - Product category rules for wood and wood-based products for use in construction” [15] by CEN TC 175. The eco-platform members are committed to using the guidance support as well as the PCR from product TCs. The Eco Platform members have started to pick up the issue and discuss the implementation in their program rules or PCR documents.

Another hurdle is the different philosophies in the publicly available databases which give rise to relevant differences in those data sets that are needed to complete the LCA and are normally not known to the manufacturer (e.g. processes of raw material acquisition, end if life processes). DG Environment plans to set up a publicly available collection of data sets pre-verified according to the PEF guidance handbook [16]. On the other hand the commercial providers of – more comprehensive- databases like GABI and EcoInvent are also making efforts to provide pre-verified data sets for the construction sector based on EN 15804.

Different member states have set up databases of EPD information or equivalent LCA results from studies to support building assessment partly required through regulations. The requirements to enter these databases are not harmonised among the maintainers of the data collections. This is a task for the Eco-platform already begun. However the obstacle of different results from different databases is not yet solved.

In order to enhance the real life applicability the eco-platform members also developed a common format with respect to a common content and order of information, also applying the inversed tables recommended in EN 15942:2011 [17] “Sustainability of construction works - Environmental product declarations - Communication format business-to-business”.

3. Conclusion

The information tool EPD based on EN 15804 is well accepted in the European construction sector. There are still obstacles in applying EPD uniformly throughout Europe. The Eco-platform shows success in a common implementation of EN 15804 by providing a common verification procedure, common EPD format allowing EPD to be accepted by all members. The applicability of Eco-platform EPD all throughout Europe is the goal for the next months. This addresses a common access to national databases and acceptance in all building rating tools. A major issue still is the difference in the background databases. A challenge is also the alignment between EN 15804 and the PEF approach. An amendment of EN 15804 to include new indicators and clarify some interpretation issues might be introduced by an amendment of the M350 for CEN TC 350 [18], which is also supposed to serve the alignment of the PEF approach with EN 15804.

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Title: Materials environmental performance data for building level assessments – a UK perspective.

Summary

In the UK, the application of LCA in the evaluation of the environmental performance of construction products has been led by BRE. Over the years, BRE had generated a materials database from LCA studies and EPD (referred to as BRE Environmental Profiles) for generic and manufacturer-specific construction products using ISO 21930, ISO 14025 and other relevant standards. This materials data was used to inform BRE's Green Guide (a decision tool that enabled comparability of construction products at a building element level) recognised in BRE's building sustainability certification schemes - BREEAM and the UK Code for Sustainable Homes. Further, a building level LCA protocol was also defined, which when used along with BRE's materials database provides a sustainability metric also recognised in the certification schemes.

The introduction of CEN TC 350 suite of standards for assessing the sustainability of construction has led to the evolution of BRE's approach to responding to sustainability assessment requirements in the UK. There is a complex interaction between the CEN TC 350 environmental assessment EN and ISO standards; and there are considerable variations in the interpretation of relevant standards that have direct bearings on how the LCA is carried out at the product level (using EN 15804), what data results from the LCA, how this data is presented, and to what level this data can be aggregated for a building level assessment.

EN 15804 implies a harmonised approach to the generation of materials data in Europe, and the potential for applying data both from within and outside the UK through database integration is critical to sustainability assessment today. This paper discusses in plain terms the underlying issues in this space.

Keywords: LCA, EPD, sustainability assessment, CEN TC 350, EN 15804

The Experience – Rules and verification processes

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Summary
ÖKOBAUDAT is a German database for the life cycle assessment (LCA) of building materials, construction and transport processes. It contains both generic datasets and specific environmental product declaration (EPD) datasets from diverse companies or associations. BMUB and BBSR, the owners of ÖKOBAUDAT, aim to present verified, consistent LCA data of building materials in compliance with standard DIN EN 15804, which shall be used in LCA for buildings. Therefore quality criteria for EPD programme operators and data sets were defined. A corresponding testing procedure was elaborated and further developed after a testing phase.

Keywords: database, EPD, LCA, verification

1. Introduction

ÖKOBAUDAT (http://www.oekobaudat.de/en.html) is a German database for the life cycle assessment (LCA) of building materials. It is made available by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) to all persons involved in building construction and hosted by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR). Building materials, construction and transport processes are described regarding their ecological effects. ÖKOBAUDAT contains both generic data sets and specific environmental product declaration (EPD) datasets from diverse companies or associations. A standardised interface of the online database enables importing of life-cycle analysis data into ÖKOBAUDAT.

2. Methodology

BMUB and BBSR, the owners of ÖKOBAUDAT, aim to present verified, consistent LCA data of building materials which can be used in LCA for buildings. EPD programme operators and data sets shall be accepted for ÖKOBAUDAT only if they fulfil defined quality criteria. Therefore 'Principles for the acceptance of LCA data in the online database ÖKOBAUDAT' were defined by BMUB / BBSR and discussed and agreed on in the ÖKOBAUDAT users advisory group.
The information in ÖKOBAUDAT is presented in form of a standardised data set format which was developed on the basis of the ILCD format version 1.1 and comprises data as well as describing text. The ILCD format was supplemented with EN 15804 requirements ('EPD data set format').

The quality criteria were transferred into a standardised process scheme with checklist and workflow. A corresponding testing procedure has been elaborated and further developed after a testing phase.

3. Results and Conclusion

The following quality requirements apply for acceptance of LCA data in ÖKOBAUDAT:

- The data have been generated in compliance with DIN EN 15804.
- The data have been verified by a third party (external verification according to ISO 14025 or external critical review according to ISO 14040 analogue to a verification according to ISO 14025). Non-reviewed data are not accepted in ÖKOBAUDAT.
- The additional ÖKOBAUDAT requirements for modelling and calculation have to be fulfilled.
- GaBi has to be used as background database (if other background data were used the equivalence with GaBi has to be proved).
- In principle, the datasets have to be delivered in German language / nomenclature. For English EPD or LCA datasets abbreviated versions and links to more detailed information in the English dataset are appropriate.
- The datasets have to be delivered in the prescribed data format ('EPD data set format').
- The valid time has to be given in each dataset.
- The owner of the dataset has released the data to be published in ÖKOBAUDAT.
- The required declarations / information have to be fully delivered.
- The datasets were subjected a plausibility check (completeness, plausibility) before approval to ÖKOBAUDAT.

The additional ÖKOBAUDAT requirements for modelling and calculation comprise

- specification of the standards (e.g. calculation of indicator 'use of fresh water', GaBi as background database),
- recommendations (e.g. modelling of end of life scenarios),
- support for the interpretation of the standards (e.g. calculation of biogenic carbon uptake).

The procedure of application and acceptance of LCA data in ÖKOBAUDAT comprises in short the following steps:

1. The applicant confirms in writing (date, signature, firm stamp) the fulfilment of the requirements in an application form and delivers the required explanations and documents of evidence.
2. The documents of evidence are checked in responsibility of BMUB/BBSR and in consultation of the ÖKOBAUDAT users advisory group.
3. After the successful check the applicant may import the data into ÖKOBAUDAT in the prescribed data format.
4. The imported data will be subjected a plausibility check and a random check in substance, where appropriate. After the successful check the data sets will be published in ÖKOBAUDAT.

A checklist was developed for steps 2 and 4, in order to guarantee a standardised testing procedure. The first EPD programme operator and their data were checked with the aid of the check list and finally released in the new version ÖKOBAUDAT 2015.

The Experience of data import and export as EPD program operator

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Summary

The EPD online tool of Institut Bauen und Umwelt (IBU) is the major platform for creation and verification of EPDs in the EPD programme of IBU. It is the basis for an interface to the national database ÖKOBAUDAT, to spread the EPD data to a wider public.

As first program operator IBU implemented it's interface for EPD datasets to the ÖKOBAUDAT successfully in 2015. Meanwhile up to 200 EPD datasets were already transferred from IBU to ÖKOBAUDAT until end of 2015. The standardized format of the interface also allows IBU to connect with other databases via the International Life Cycle Data system (ILCD). The format datasets are transferred by XML-files.

Introduction

The development of EPDs within IBU as program operator takes place in the epd-online tool (https://epd-online.com). The whole process is web based, which has several advantages for the users: the tool has a multi-user functionality, so all participants can work in an EPD document simultaneously including the independent verifiers, who get access to the EPDs with the assignment. Furthermore this function also eliminates error sources, e.g. working in different versions of an EPD as a Word file exchanged via email. The tool is also adaptable to new requirements for EPDs or the EPD developing process as well as an integrated multi search function. IBU attaches importance to a tool with easy handling which is available in English or German. In addition to an individual introduction for every user via webinar and ongoing support if needed, there is a permanent optimization of the tool. The latest development is an offline editor (IBU lightning Editor) which allows the user to create the EPD offline and upload it to the online tool. Through several mechanisms it is ensured also in this tool that a user will not delete or overwrite the work of other users in the same EPD. Because everything takes place online, almost the entire EPD is suitable for further digital processing. This makes it an ideal basis for an interface between the IBU online tool and the database ÖKOBAUDAT.

Implementation

The implementation of the interface started in 2014 and was finished after several corrective measures by summer 2015in coordination with the BBSR (Federal Institute for Research on Building, Urban Affairs and Spatial Development). During the developing IBU met some difficulties for the implementation of the interface: One problem was to get specific interpretations about the required input in some sections of the dataset (e.g. a definition for the input in the field technology description including background system). Another challenge was the handling of different scenarios in EPDs. For example two scenarios for the End of Life phase with e.g. 100 % recycling or 100 % disposal. Additionally the preparation of the datasets is important, so that they can be used in manifold software tools like a tool for building LCA. Therefore some information like density etc. are essential, which can be read by software.

At an early stage of the implementation, some major advantages of the interface emerged already. The error prevention is to be mentioned here, because the information to be transferred are generated automatically from the verified and published EPD out of the epd-online tool. It also provides the user the opportunity to attach additional information to the dataset (e.g. a safety datasheet). By using the ILCD format IBU has the option to provide its datasets also for other databases than ÖKOBAUDAT.

With this development IBU generates additional services for its members and declaration holders. The interface to ÖKOBAUDAT is easy to handle. About 90 % of the dataset (XML file for ÖKOBAUDAT) is generated automatically. The owner of the declaration only has to provide or select some additional information and may give further information in form of attachments. In order to provide help for finalizing the dataset in the IBU online tool interface IBU published a video which explains very easy how to use the interface.

The prepared dataset will then undergo a plausibility check by IBU and is then shifted to the inbox of the BBSR to be published afterwards in the ÖKOBAUDAT. IBU will has transferred about 150 datasets within two deliveries (stand 11/2015).

Results and Conclusion

The datasets are delivered in a form that they can be used in further software tools (like the eLCA bauteiledior.de) for building life cycle assessment. The technical data are also in a digital format and can therefore be processed. So users of a building assessment software tool are able to easy calculate their own buildings with specific EPD data.

Prospectively IBU's aiming on opening the ÖKOBAUDAT for English datasets Another concern of IBU is it to also give EPD owners, not using GaBi for the EPD creation, the chance to publish their data in the ÖKOBAUDAT. The challenge here is not to mix datasets which are calculated with different background databases. Here the BBSR offered a separate solution within a separate section of the German national database.

Through the above explained and provided digitalization of EPDs the overall goal of more sustainability within the whole planning and construction process of buildings is possible.

Towards a European Data Network for Construction Product EPDs

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Summary

Quality Environmental Product Declaration (EPD) data which is compliant to EN 15804 is an important foundation in order to assess environmental impacts on building level as it is required by certification schemes such as BNB or DGNB. As more and more data becomes available across Europe, the ability for users performing building level calculations to locate the suitable datasets becomes an important factor. Given the availablity of a proven technology stack with both open source and proprietary licensed software which already allows to build data networks, stakeholders across Europe are considering to leverage the existing technology in order to build an experimental data network for EPDs, which then can be used to distribute data as well as to identify potential gaps and issues that may need to be addressed in the course of the ongoing harmonization efforts.

Keywords: EPD, construction products, data network

1. Introduction

The ÖKOBAUDAT, a free public database for Environmental Product Declaration (EPD) data on construction products operated by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), a research institution under the portfolio of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, is a pioneering effort when in comes to publishing harmonized and high-quality environmental data on construction products. The database can be seamlessy accessed by calculation tools in order to assess environmental impacts on building level, addressing the needs of certification schemes such as BNB or DGNB.
As other European actors have voiced the need for sharing data internationally and mutual recognitions are being driven forth by program operators, it has been considered to join forces with other European EPD initiatives in order to pursue the vision towards an experimental European data network for EPDs.

2. Building a Data Network

EPD data usually is published in form of a PDF document. As a prerequisite for publishing on the data network, however, it needs to be available in a structured, machine readable format, since other tools rely on the data for calculation. For the ÖKOBAUDAT, the widely-used ILCD data format which was published by the European Commission has been has been fitted with some additonal extensions in order to address the needs of the EN 15804. This format has already been implemented in open source software tools such as openLCA or proprietary solutions such as GaBi or the IBU Online tool, as well as simplified LCA tools such as the open source eLCA which is used to calculate impacts on building level based on EPD data.
That means that in a first step, existing EPD data from parties interested in joining the network needs to be rendered in machine readable form using the ILCD format.

The software that is used to run the ÖKOBAUDAT has originally been conceived as a general-purpose database application to host LCI and LCIA data in the ILCD data format. It has been published under the name soda4LCA, which stands for Service Oriented Database Application for LCA, and under the open source GNU Affero General Public License (AGPL). The soda4LCA software is widely used in the scientific domain to publish results as well as to host a number of national and international LCA databases. Furthermore, it is the reference implementation for the European Commission's Life Cycle Data Network (LCDN).

As the soda4LCA software serves as the technical infrastructure of the German ÖKOBAUDAT database and it already allows for joining nodes together to form a data network (just like it is done for the LCDN), other data providers, program operators or national institutions could just leverage the tool to host their own nodes in order to publish their data. All of these nodes, together with the German ÖKOBAUDAT, could then be joined together to form a network of independently operated databases. This scenario would allow users to search the entire network from a single entry point (which would be any node), while at the same time, data providers and national organisations maintain full physical control of the data they're publishing.

3. Conclusion

Given the availability of the necessary IT tools, a data network would be a way to distribute and publish data more efficiently across Europe and internationally. The advantage of a data network of independently operated nodes is that while potential users gain access to a vast pool of quality data, data providers stay in full control of their data.

The proposed solution builds upon established standards and technology and could serve as an opportunity to identify potential gaps and issues that may still need to be addressed in the course of the ongoing European and international harmonization efforts.

Authors: Artur Borowczyński, Dariusz Heim

Title: Assessment of daylight conditions in the office room equipped with reflective louver system

Abstract: Determination of indoor daylight condition using selected types of blinds or louver system are well described when material is opaque and plays a role of shading device. However, in some specific cases transparent or semitransparent elements are able not only to protect from overheating but also to provide required and useful amount of daylight. For some specific window construction the location of louver system can be determined by a sun position or required level of internal illuminance. Additionally, taking into account surface properties e.g. roughness, reflectiveness or angle dependence of total transmittance, it is possible to determine optimal tilt angle of the slats.

In the presented study authors investigated the effect of transparent louver blind with highly reflective outer layer on stimulating daylight level in building interior. For the purpose of full scale experiment, two experimental office rooms were developed and equipped with illuminance sensors. Both rooms were oriented in the opposite directions: west and east, with one window centrally located in the wall. Windows were equipped from outside with the highly reflective, flat and moveable glass blinds. Experiment was conducted during selected days of summer under sunny and cloudy weather conditions. Weather conditions were monitored using basic sensors for solar radiation as well as digital images of the sky. Experimental results were compared for selected blinds position to estimate the effect of additional daylight system on useful daylight illuminance inside the office room.

Energy efficiency of experimental BIPV façade in high temperatures

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Summary

The presented study is devoted to assess the effect of temperature and solar radiation on efficiency of the experimental BIPV façade. Measurements were done during warm September days for east and west oriented BIPV facades constructed from CIS modules. This configuration provides very low angle of incident in a morning and afternoon hours what gives the high amount of solar radiation reaching solar cells and consequently lead to high energy efficiency of BIPV facade. The selected PV system parameters like voltage, current and power were monitored by DC measurer. Additionally meteorological station collects data of climatic conditions. Finally, obtained experimental results show the correlation between PV power output and climatic conditions like solar radiation and temperature.

Keywords: Building Integrated Photovoltaic facade, climatic conditions, measurements, experimental study

1. Introduction

In European Union countries significant emphasis is placed at improving building energy performance to zero- or almost zero-energy standards. Particularly considering aims introduced by EU that by the end of 2020 all new buildings should be “nearly zero energy”. Considering these requirements besides increasing thermal insulation of the external building partitions there is also necessity to utilize building envelope to produce electrical or thermal energy from renewable sources. One of the most promised solution is using PV panels, widely described in the literature [1-3]. Photovoltaic technology can be applied as Building Integrated Photovoltaic (BIPV). PV panels replace traditional elements of building envelope by active components equipped with photovoltaic cells [4]. Therefore photovoltaic systems not only produce electricity, but also perform the function of the building envelope. Application of BIPV systems is the most profitable in office and public buildings where electricity consumption has the highest share in energy demand profile during working hours which is coincident with availability of solar radiation and hence in photovoltaic electricity production. Therefore BIPV is a very favorable solution especially when the internal electricity grid is connected to the outer network. Use of utility energy grid as a virtual storage system allows obtaining energy balance over long term period e.g. one year.
The aim of presented paper is the analysis of the efficiency of the experimental BIPV facades located in central Europe. Studies are made basing on measurements of existing photovoltaic installation’s electrical performance and climatic conditions represented for analyzed area.

2. Experimental BIPV façade

3.1 Geometry of BIPV façade

Presented studies are devoted to analysis of two: east and west oriented experimental BIPV facades located at the 4th floor of existing building. Geometry and construction of the analyzed photovoltaic facades were determined in the frame of the multi-criteria optimization procedure taking into account energy, economy and environmental factors [5,6]. External partition of the experimental façade consist of 8 CIS panels located around the centrally positioned window as is shown in scheme in figure 1. Photography of the existing experimental BIPV façade is presented in figure 2.

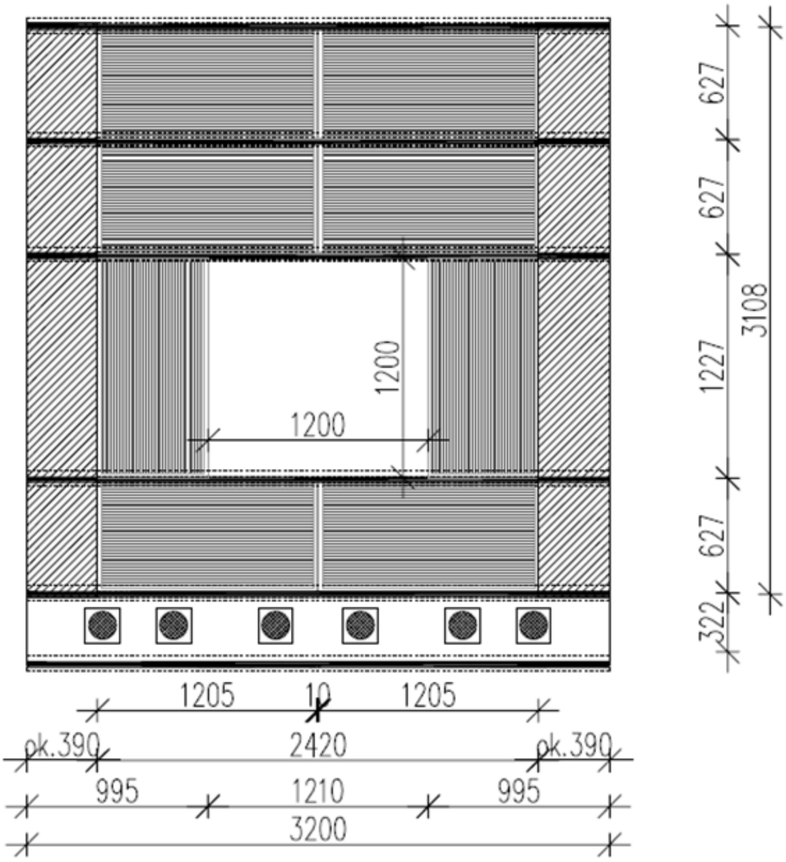


Fig. 1 Visualisation of the experimental BIPV facade

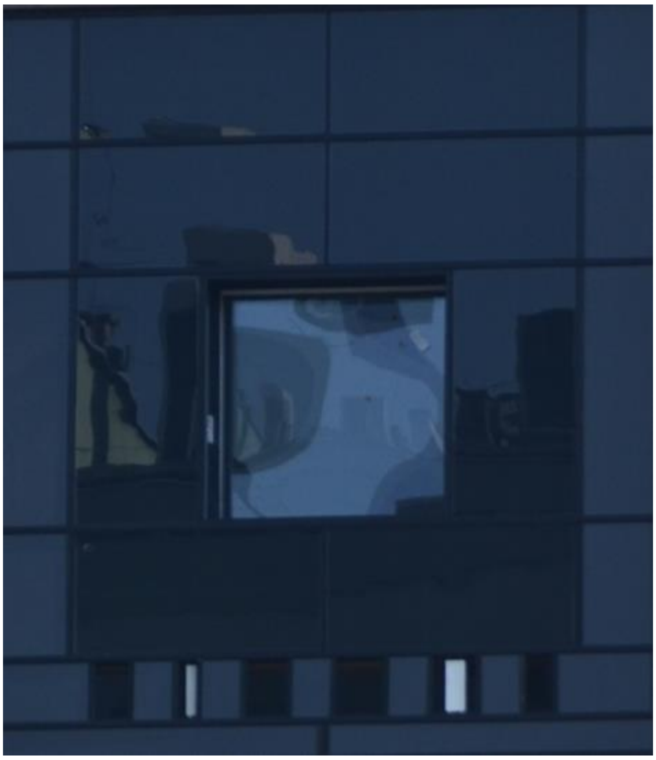


Fig. 2 Picture of the existing experimental BIPV facade

Two basic generations of solar cells were considered to use in experimental facade: crystalline (Monocrystalline and Polycrystalline Silicon) as well as thin film (Amorphous Silicon, Cadmium Telluride (CdTe) and Copper Indium Selenide (CIS)). The following parameters were taken into account: efficiency, weight and price of PV panels as well as area needed per kW. Additionally, according to destination of PV panels at the building façade the appearance of them was also considered. Finally, CIS thin film panels were selected because of the best relation of efficiency to the price, low weight, commercial availability and attractive appearance. Electrical parameters of PV panels used in experiment are presented in table 1. Each PV module measuring 1205 x 605 mm is situated in rails and can be positioned horizontally or vertically. Selected CIS panel consist from three layers: 3 mm exterior glass, photovoltaic layer and 3 mm back glass framed in an aluminum anode frame.

Table 1: Electrical parameters of selected CIS panel

Parameter	Value
Efficiency	12%
Nominal power	80 [Wp]
Voltage at MPP	35 [V]
Current at MPP	2.3 [A]
Open circuit voltage	44.02 [V]
Short circuit current	2.5 [A]

3.2 **Electrical installation**

Both photovoltaic installations located at east and west facades of the Lodz University of Technology building are connected to the individual off-grid electrical systems containing charge controllers, bank of batteries and inverter (figure 3). Each BIPV façade is divided into two parts, left and right, consisting of 4 PV panels which are connected in series and then parallel. Consequently maximum electrical parameters of one part of the façade are:

- Nominal power: 320 Wp,
- Voltage at MPP: 70 V,
- Current at MPP: 4.6 A.

Firstly, current generated by one part of photovoltaic system is delivered to the DC measurer to monitor and make measurements of produced electricity. Subsequently current is passed to charge controller which control battery charging process. Simultaneously, current from both parts of the façade is passed to the two charge controllers connected with common bank of batteries. Next, current from bank of batteries is transmitted to the receivers by inverter which transforms direct current into alternating current. Energy generated by photovoltaic system is dedicated to power local underfloor ventilation unit and artificial lighting. Additionally it is possible to collect electricity from the network by inverter in case when energy produced by photovoltaic façade is insufficient.

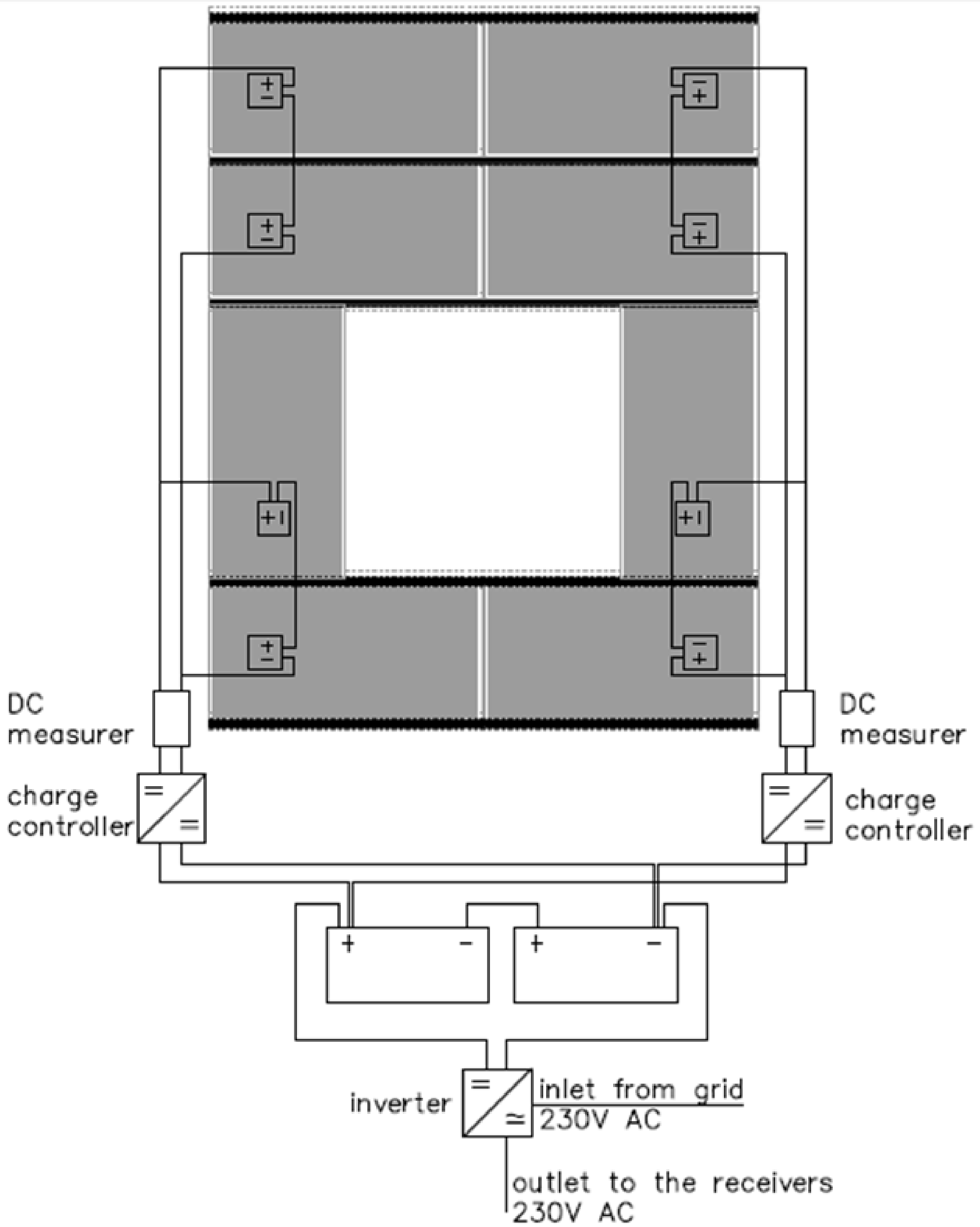


Fig. 3 Scheme of the electrical instalation of the individual BIPV facade

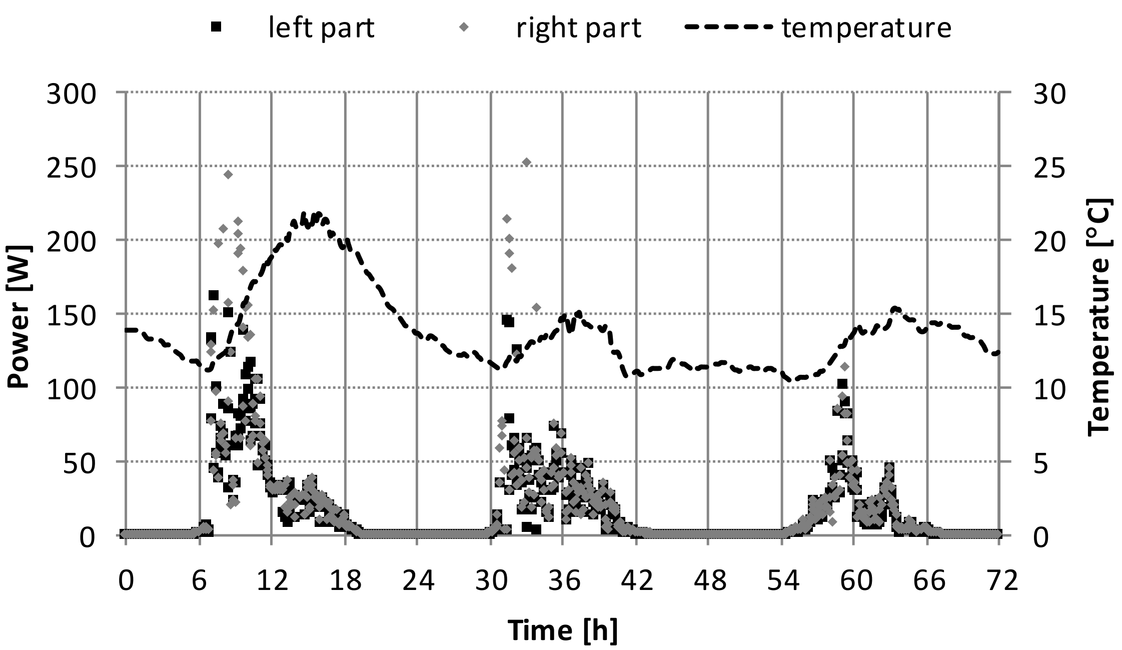
4. Case study

Presented analysis based on the experimental data from DC measurers located in off-grid electrical grid, which measure current and voltage generated by photovoltaic arrays. Additionally, there were performed measurements of ambient temperature and solar radiation in the meteorological station located at the roof of building where experimental facades were installed.
Experimental setup was placed in moderate climatic conditions in the central Poland at the building of Lodz University of Technology. Measurements were performed during September, but because of the gaps in the measurement caused by power disruptions for meteorological station, in presented paper we focus on two 3-days periods from the beginning (5-7.09) and ends (25-27.09) of September characterized by different range of temperature and various type of sky.
All measurement data are presented in the form of graphs considering different orientations of the BIPV facades and two periods of time.

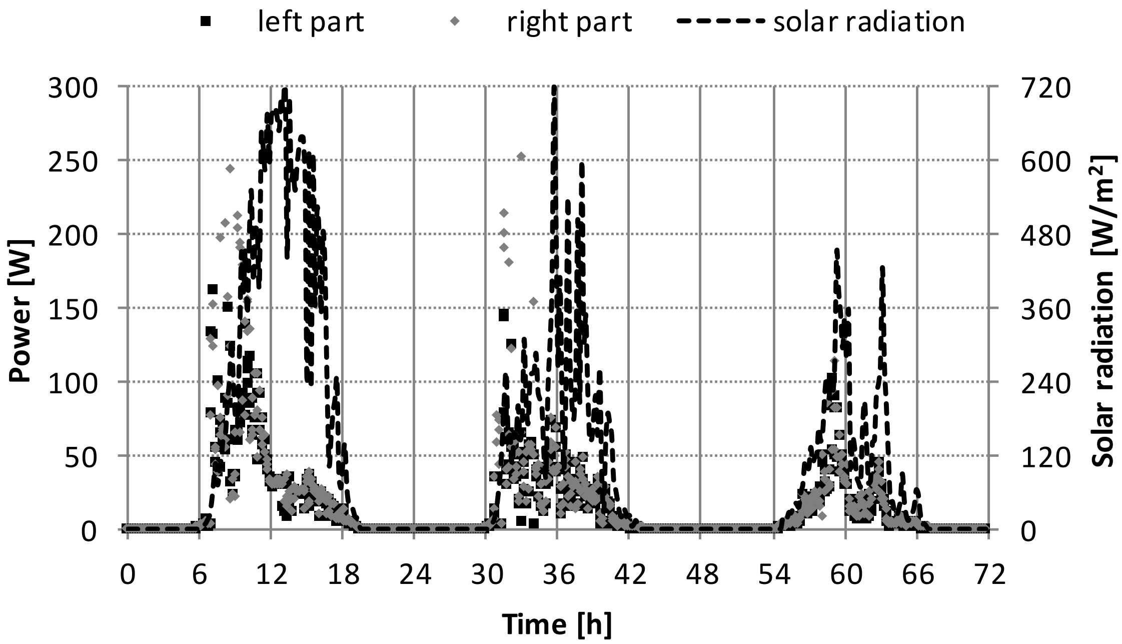
5. Results

5.1 East oriented BIPV façade

Graphs in the figure 4 present power generated by individual parts of east oriented BIPV facades with temperature (a) or solar radiation (b) profiles in first analyzed period. It can be seen that amount of power produced by both analyzed parts are very similar. The highest amount can be noticed for the morning hours, because of the vertical configuration and east orientation of the BIPV façade. Additionally the power graph shape is correlated with profile of the temperature and solar radiation. In morning hours, when the angle of incidence of solar radiation and temperature are low, power generated by PV installation is high and achieved even 200 W. During later hours in the absence of direct radiation exposure power produced by PV panels is higher second day when temperature is lower.



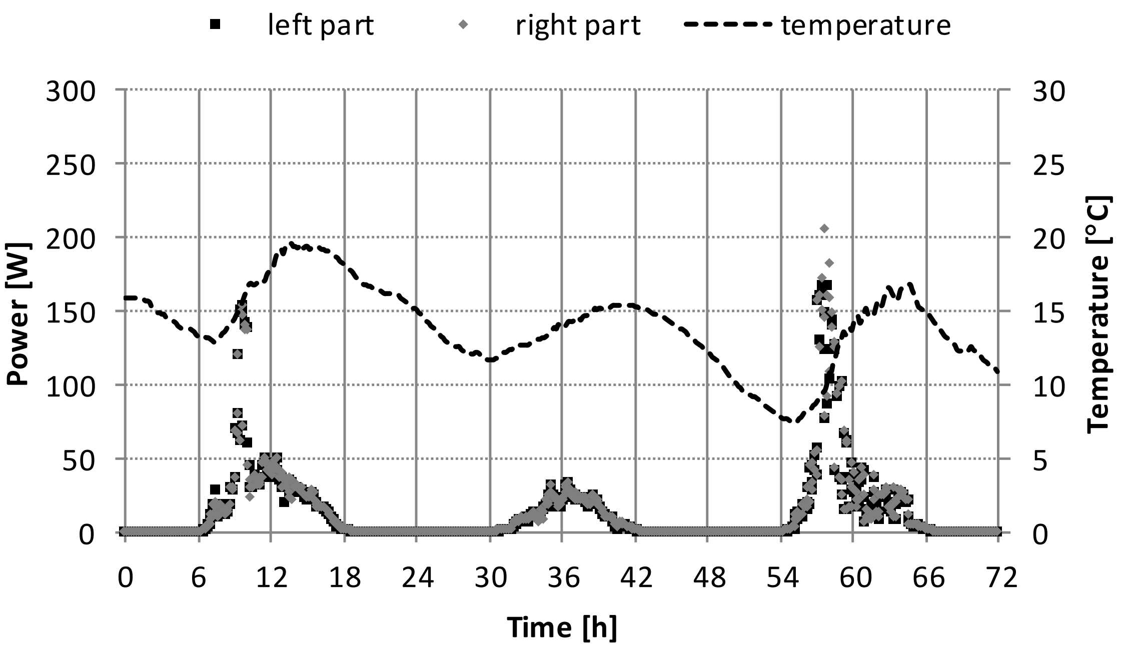
a)



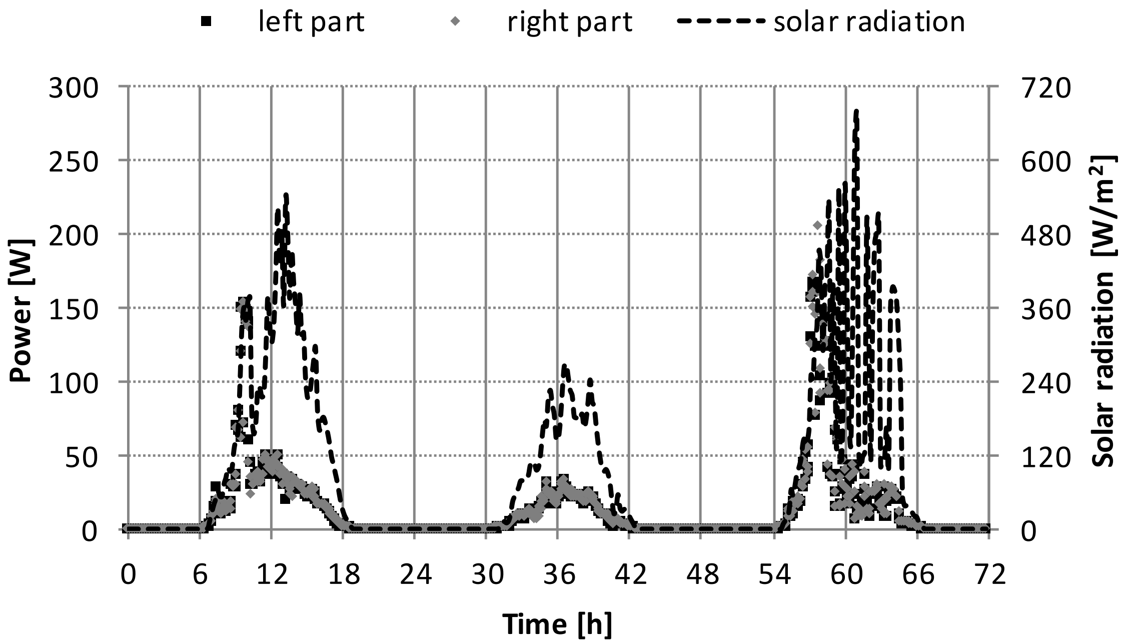
b)

Fig. 4 Power generated by individual parts of east oriented BIPV facades with a) temperature, b) solar radiation in 5-7 September.

Next, the figure 5 shows power produced also by east oriented BIPV facades at the end of September. Similar to previous period, results for both parts of BIPV façade are converge. In second analyzed period level of solar radiation is lower therefore amount of power generated by PV installation is also lower. Furthermore, in second day when only diffuse radiation exposure can be seen, the power is very low and quite stable during a day.



a)

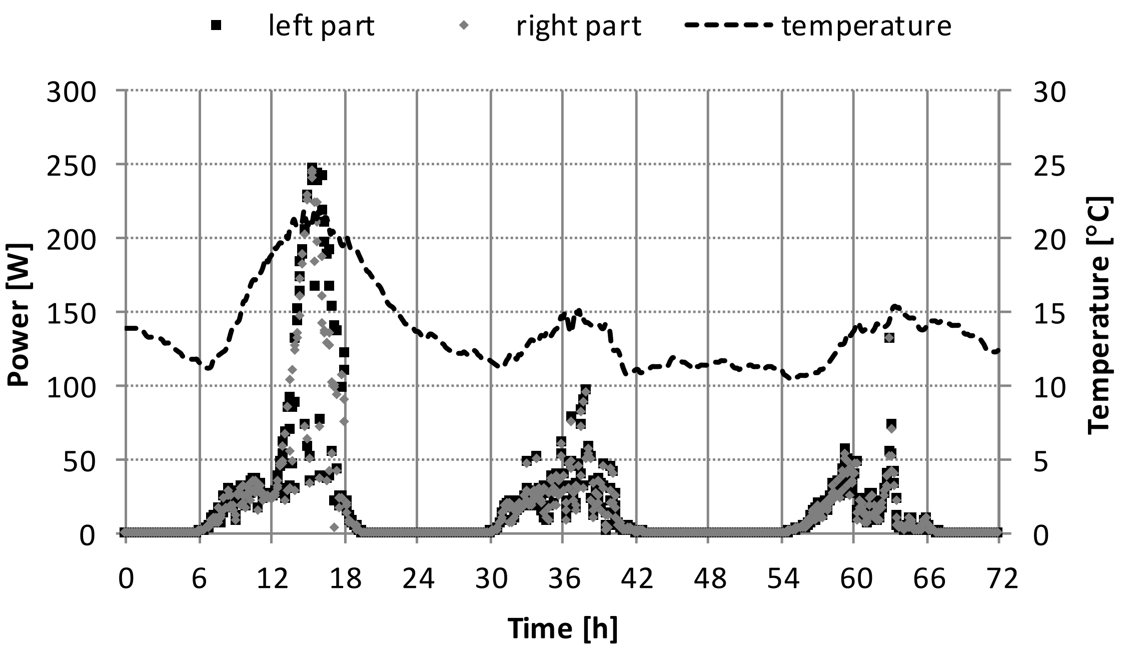


b)

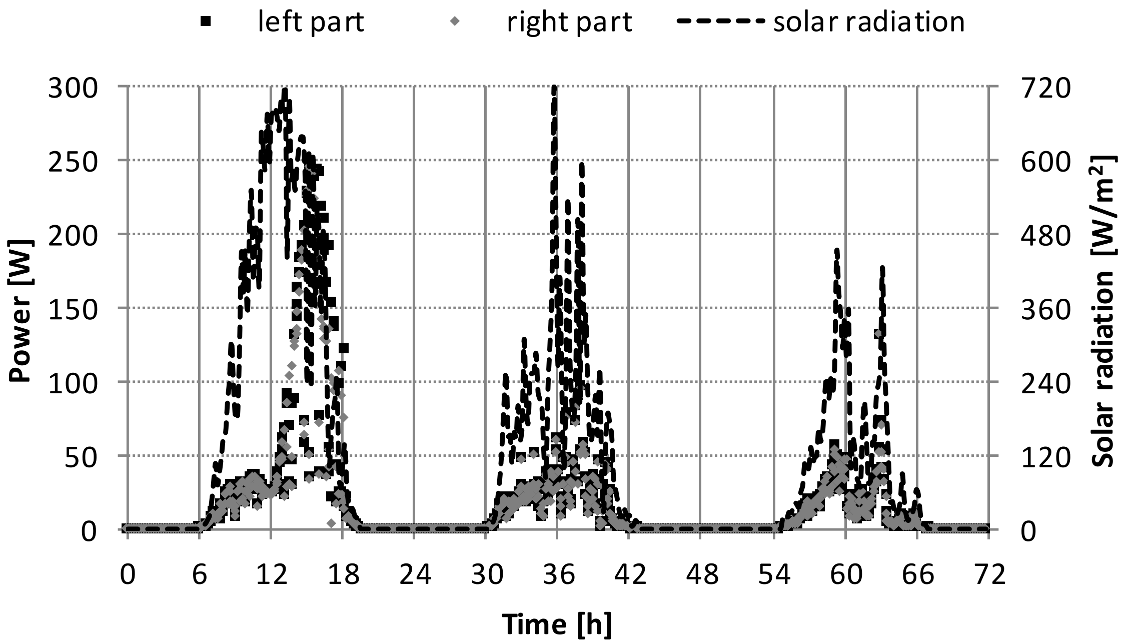
Fig. 5 Power generated by individual parts of east oriented BIPV facades with a) temperature, b) solar radiation in 25-27 September.

5.2 West oriented BIPV façade

Subsequent graphs in the figure 5 present measurements from west oriented BIPV in first analyzed period. Like for east oriented façade the results noticed for right and left parts of the BIPV façade are comparable. Higher power of electrical energy for west oriented PV installation is seen during evening hours when solar radiation incident directly on this façade. Furthermore the highest power almost 250 W can be noticed for first day.



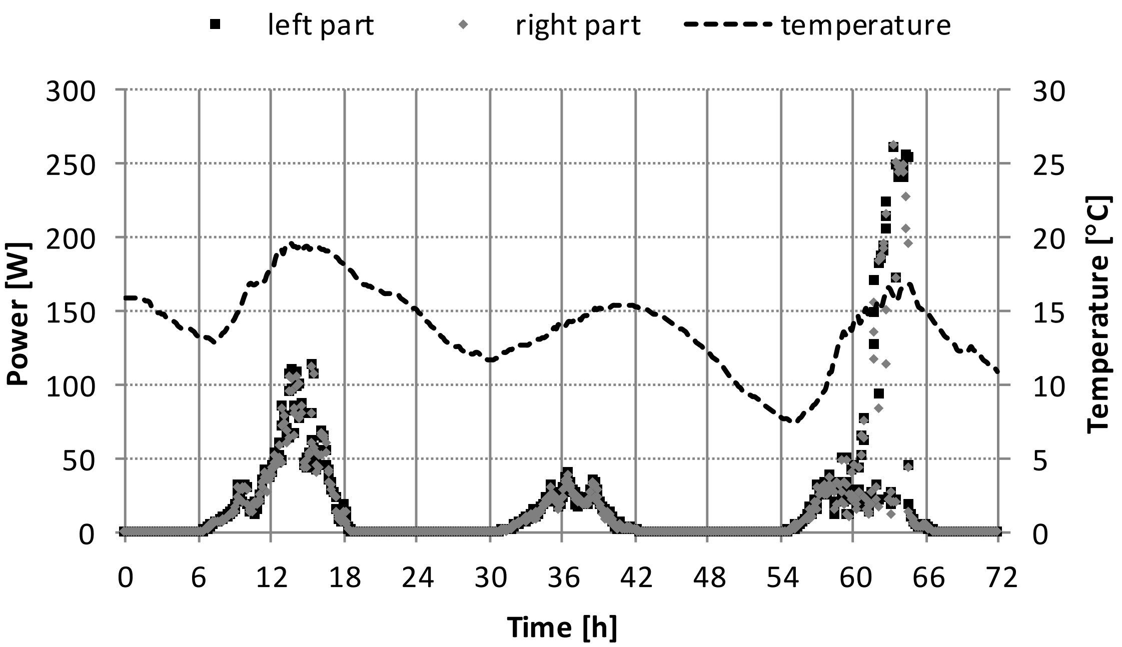
a)



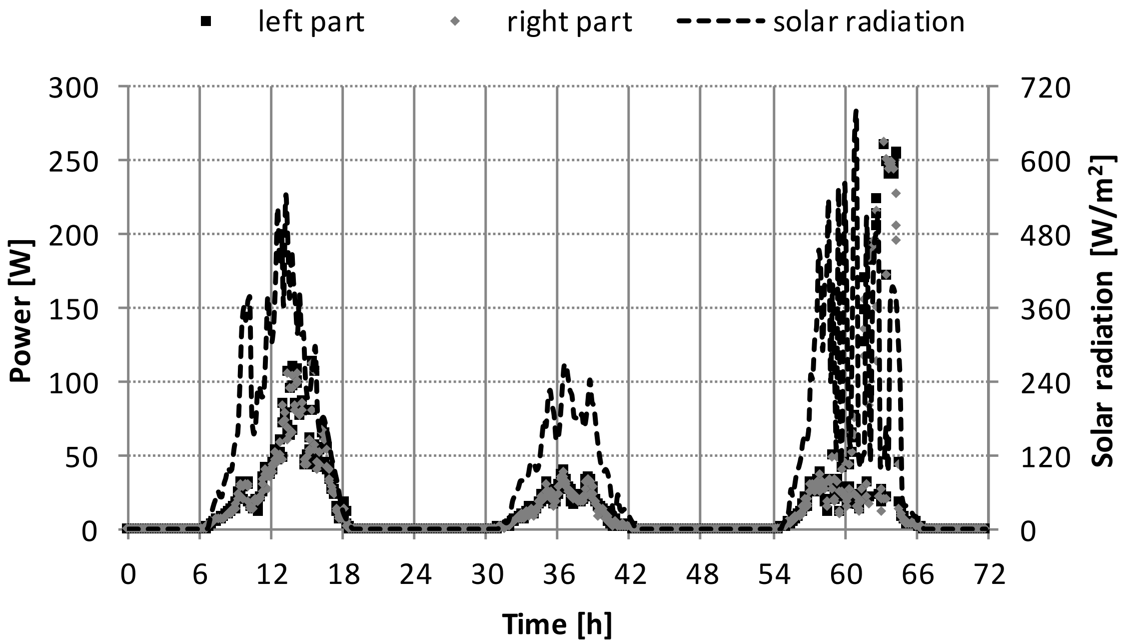
b)

Fig. 6 Power generated by individual parts of west oriented BIPV facades with a) temperature, b) solar radiation in 5-7 September.

Graphs presented in the figure 6 shows measurements for west oriented BIPV façade in second analyzed period. Similarly as in previous results, power generated by both parts of BIPV façade is almost the same. Like for east oriented façade in second day with diffuse radiation exposure the power is significantly lower and not various during day. The highest amount of power can by noticed for third day.



a)



b)

Fig. 7 Power generated by individual parts of west oriented BIPV facades with a) temperature, b) solar radiation in 25-27 September.

6. Conclusions

In presented paper measurements of the power generated by experimental BIPV facades were analyze for selected days of September. Investigations were made based on data of electrical performance of the existing photovoltaic installation as well as weather parameters recorded by meteorological station. Presented results confirmed theoretical assumptions that east oriented PV installation generate the highest amount of power in morning hours and west oriented one during evening hours. Furthermore, both BIPV facades produced electricity during a whole day, even during diffuse radiation exposure. However, with absence of direct solar radiation the maximum power of electrical energy is significantly lower. Moreover, it was noticed influence of high temperature on decrease of power generated by PV installation.

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Authors: Anna Machniewicz, Dariusz Heim

Title: Temperature distribution in the mineral wool insulation component enhanced by PCM external covering

Abstract: Stimulation of the building external surface temperature leads to significant reduction of heat flux by conduction. Even during cold winter months the solar radiation affecting external layer can heat up the surface above indoor temperature. From the energy point of view the most effective strategy is to keep stable temperature of external surface at the level of indoor one for the longest possible period of time. Considering a highly insulated external wall the direct solar heat gains by conduction are negligible. However, stabilization of external surface temperature always leads to additional energy savings and improves overall energy performance. Such an approach can be a reasonable alternative for significantly increasing of thickness of thermal insulation.

In the presented study authors proposed the unique, original solution of insulation layer enhanced by PCM coating from outside. The properties of PCM composite were investigated experimentally. Additional layer was applied on traditional mineral wool insulation and placed in an experimental, real scale façade installation. The external part of the wall was constructed as a rain-screen ventilated façade system exposed to solar radiation. The partition was equipped with platinum resistance thermometers and tested during intermediate period. The temperatures in characteristic locations were compared with temperature of traditional wall, without PCM layer. Additionally, the basic weather parameters were recorded during experiment. Based on the experimental results the effect of latent heat storage on temperature distribution in the wall was estimated.

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