FINAL REPORT

EDRC –

European Demand Response Center

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PART 4: Potential allocation and simulation of possible impacts in Austria (Graz University of Technology)

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1 Demand-Side Management Basics

There are two different methods for Demand-Side Management (DSM). One method being the reduction of consumer-sided load, the other being a short term unscheduled increase in generation. It is also possible to increase the amount of delivered energy.

The purpose of unplanned load management is to maintain system stability, which can be refunded by the grid operators, or to gain profits for the company applying this DSM method. To achieve such an overall load shift a company can either interfere with the operational process flow, if no penalties result from the loss of production, or by shifting process independent loads. Both measures will, if used correctly, increase the system stability and furthermore increase the total efficiency of the system (e.g. by reducing the needed balancing energy). The methods for load shifting described are shown in Figure 1.

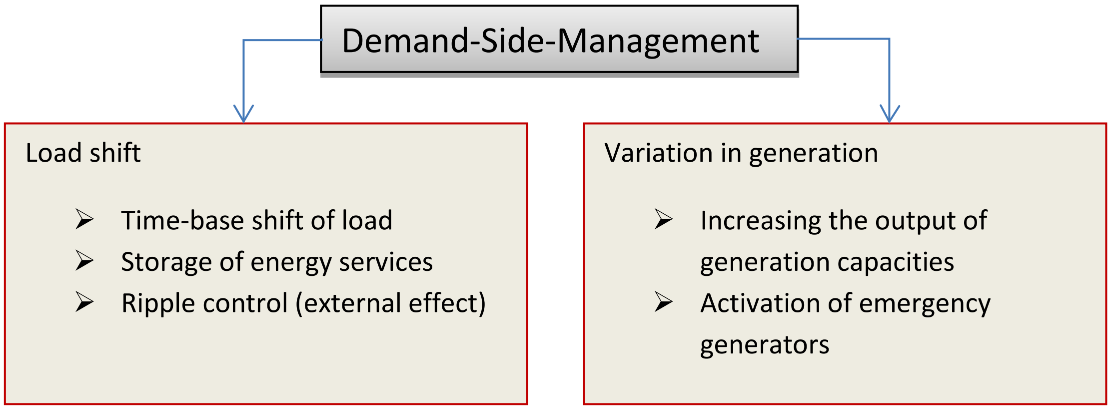

Figure 1: Possibilities for consumer load management

Depending on size and branch of an industrial company several options to save money through the use of DSM-methods occur. Beside the financial gains for the company, using DSM will affect the overall security level of supply and may even lead to a decrease in energy prices. Lower energy prices can be the result of DSM if it is used appropriately, meaning if a company can shift its load from times of peak load to off-peak-times. Lower energy prices can be passed down to all end consumers which leads to lower production costs for the company itself and therefore strengthens the position of an industrial company.

1.1 Positive and negative aspects of DSM

Advantages of a reaction of consumers to critical or unpredictable situations in the electricity system:

- **Fast and uncomplicated:** Certain industrial load shifts are prepared for specific assignments and can therefore react very fast if needed. The most important requirement is the existence of an appropriate contract with the DSM supplying company.
- **Reduced capacity demand from power plants:** Through the use of DSM investments in transmission lines or energy-producing-facilities can be postponed. Additionally the use of existing power plants can be more efficient. The entire electricity system needs to be able to handle the annual peak load (in addition to certain reserves). This annual peak load can be

reduced through DSM which aside from reducing the demand for the entire electricity system also leads to a homogenisation of the load curve. This result in a more efficient use of power plants (compare Figure 2).

- **Low costs:** The electricity sector has very high costs when it comes to the construction of new infrastructure. The implementation of DSM on the other hand can be rather cheap and has under normal conditions rather short payback-periods.
- **Higher efficiency and environmentally friendly:** The use of DSM leads to generally more efficient electricity system. This results in a reduced demand in primary energy carriers. The more efficient use of energy-producing facilities leads to a reduction of emissions and therefore has a positive impact on the environment.

Possible disadvantages of a consumer reaction to an unpredictable situation in the electricity system:

- **DSM may send wrong price signals:** Through the re-dispatching of demand and production and the simultaneously occurring shift of the resulting cost to the network tariffs (costs for DSM are rolled off on the network tariffs) the information of congestion is lost for the free market. This may even result in wrong congestion-signals for the market because congestions won’t be detected under certain circumstances. The implementation of DSM can therefore result in negative effects on certain congestion-situations.
- **No long-term solution for capacity problems:** DSM may provide short term solutions for problems in energy-production or energy transportation but cannot replace long term development of net or power plant development strategies.

2 Possible designs for Demand Side Management

The following applications for DSM-measures in the transmission grid of continental Europe can be identified:

- Balancing energy market
- Peak load reduction, especially if energy production capacity is secured
- Avoidance of peak prices for energy consumption
- Minimization of balancing energy costs in a balance group
- Removal of predictable network congestions
- Emergency measure for securing the system stability in exceptional situations

2.1 Balancing energy market

The three different balancing energy markets in Austria, primary-, secondary- and tertiary-reserve, are open to every participant of the electricity-economy since 2012. The tertiary-reserve market is especially attractive for DSM due to its relatively long lead time. One of the things which need to be discussed is the “form” of the supplied power, which should have a ramp-like shape. Table 1 shows the current conditions in Austria’s balancing energy market.

Table 1: Overview over the balancing energy markets in Austria (Austrian Power Grid AG, 2011c)

Balancing energy market	**Contract volume**	**Duration of offer**	**Possible products**	**Prequalification**
Primary	± 76MW	Weekly (minimum size 1MW)	Weekly Monday to Sunday	(Austrian Power Grid AG, 2011a)
Secondary	± 200MW	Weekly from 2012	Week/4 week Products separated into peak and off-peak as well as weekdays and weekends	(Austrian Power Grid AG, 2011b)
Minute (Tertiary)	+100MW/-125MW additionally 180MW to prevent the shutdown of the largest generation unit	Weekly (Market Maker) as well as daily for the next day	Market Maker: Weekdays or weekends in blocks of 4 h (power- and energy payment) Daily (only energy payment)	(APCS, 2004) is no prequalification constraint at all

2.2 Peak load reduction

The most important use of DSM is to reduce load in peak load times (see Figure 2). These few peak hours in a year create a demand for supply reserve, leading to high specific fixed costs. For example, the costs for a combined cycle gas power plant with an installed capacity of 400 MW are approximately 280 mio. €. These costs need to be compared to the costs of shifting certain load-intensive processes (e.g. grinding process in a cement plant) from peak load times to off-peak times. Since peak load hours make up only a small proportion of a year, this shift should be rather uncritical for the company, depending on their process structure. The building material industry qualifies very well for peak load reduction as the demand in building material is significantly higher during summer times whereas the peak load hours mainly occur during winter.

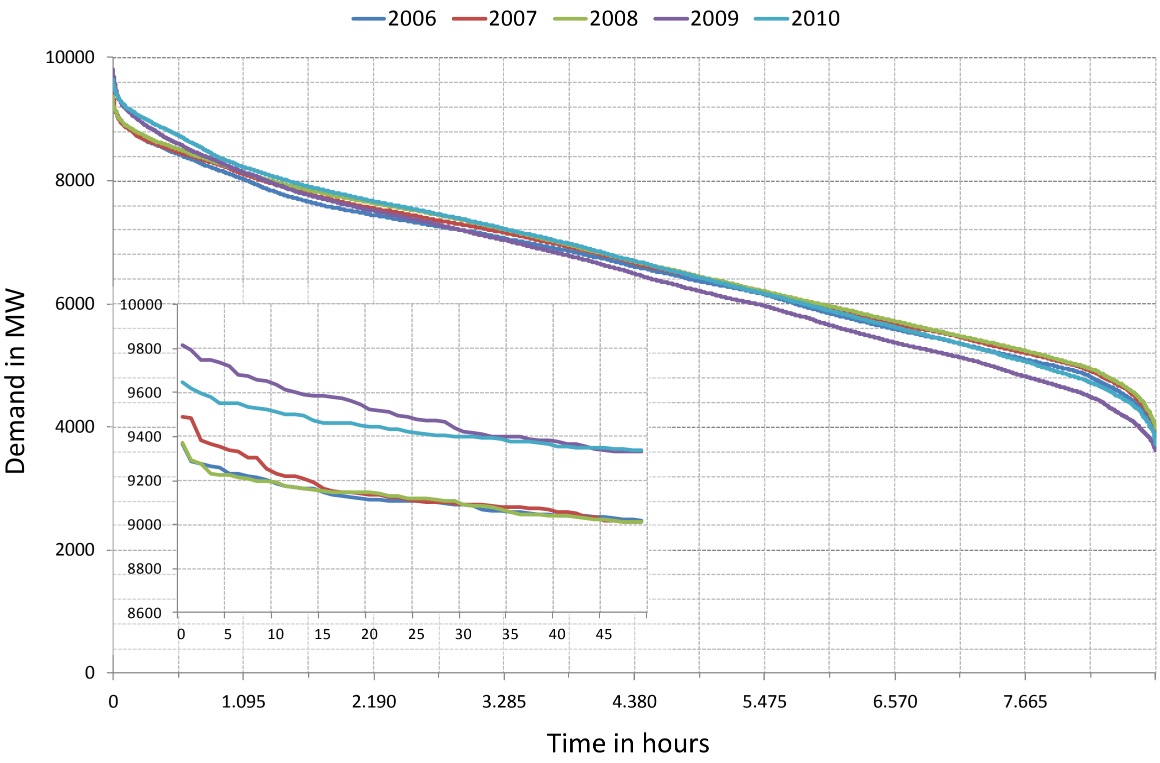

Figure 2: Demand curves for the years 2006 to 2010 (source ENTSO-E)

2.2.1 Current peak load situation in Austria

Figure 2 shows the consumer's electricity demand in Austria for the years 2006 to 2010. It is obvious that for a limited period of the year the demanded power is very high, a more detailed perspective is provided in the enlarged part of the diagram. For the year 2009 there is a demand increase for the 40 highest peak load hours of approx. 449 MW. These 40 hours are distributed over 12 days. In general there is to see an absolute peak of 500 to 600 MW for about 20 days in a year from 2006 to 2010. This circumstance promotes the use of DSM for the reduction of peak load. Figure 3 shows the distribution of the 88 hours with the highest load situation in a year. Figure 4 and Table 2 show at which hours of the day those peaks occur.

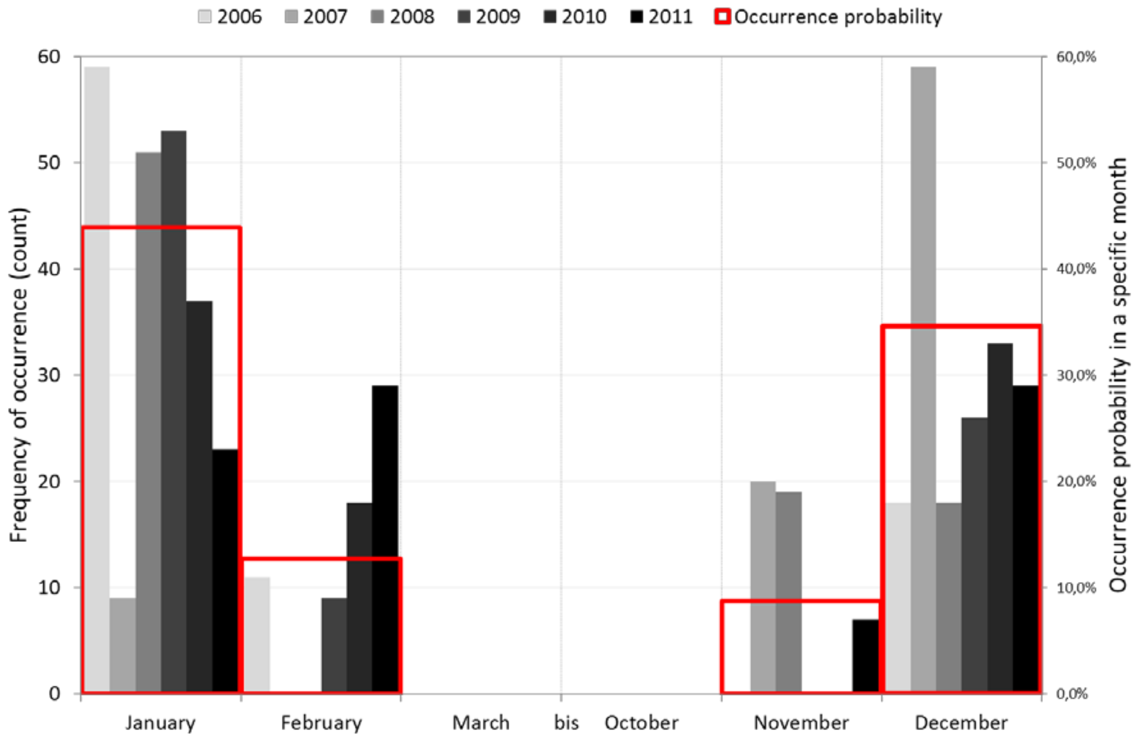

Figure 3: Peak load situation in Austria from 2006 to 2010 monthly categorisation (data source: ENTSO-E)

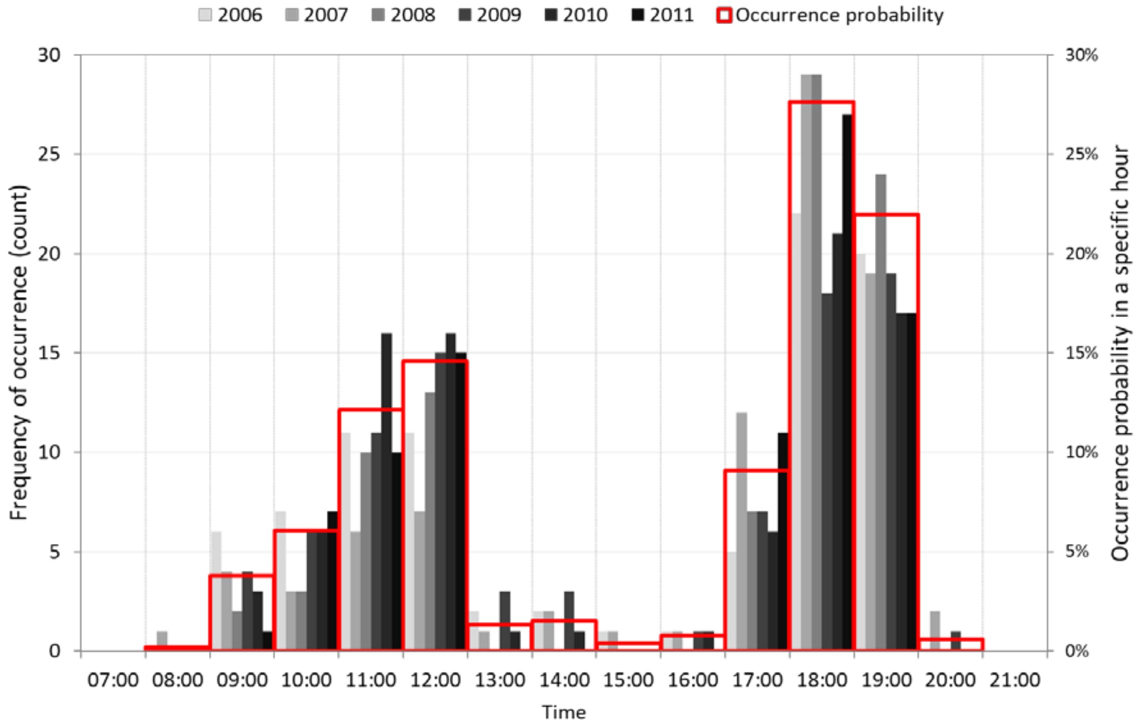

Figure 4: Peak load situation in Austria from 2006 to 2010 hourly categorisation (data source: ENTSO-E)

Table 2: Overview over the possibility of peak load occurrence categorised after months as well as hours (red frame in the diagrams above)

Month	Possibility	Time	Possibility	Time	Possibility
January	47%	7	0%	14	2%
February	9%	8	0%	15	0%
March	0%	9	4%	16	1%
October	0%	10	6%	17	8%
November	9%	11	12%	18	27%
December	35%	12	14%	19	23%
		13	2%	20	1%

2.3 Avoiding price peaks for energy demand

On the continental European energy market very high peak prices can occur in extreme situations. During the winter months with a high demand and a reduced production from hydro-power plants, relatively high energy prices may result during peak hours. This is a problem for load intensive companies, because their electricity bill matches the hourly market price. As a result, it can be useful for certain big companies to reduce their load during peak times. The decision to reduce load depends on the opportunity costs for the reduced production as a result of the load reduction. These costs depend on a variety of factors. For example, the loss of production capacity can become extremely expensive if it results in a delay of delivery leading to high penalties. In certain industries a reduction of load isn't possible due to the nature of the production process, which would lead to high opportunistic costs, as would be the case in the NE-metal producing industry. An entirely different situation is given when you look at the Stone- und Earth-industry as well as paper-, iron- or metal producing industry. Ideally certain production steps can be shifted from peak times into off-peak times, especially those steps which produce a commodity which can be stored for later usage (see chapter 3.2). Through that method high peaks in energy prices should be avoided. In addition, if the company owns a generator, unused energy can be sold on the market. This is also true for back-up generators.

Over the last years the promotion of fluctuating renewable energy producers (e.g. wind- or solar power) on the Austrian and German energy market has led to situations where the price for energy drops drastically or the renewable energy didn't find a buyer on the market. These situations lead to an interesting new possibility for the use of DSM. The drop in energy-prices enables companies with the possibility for DSM to shift their production into these times so they can produce a storable commodity at very low prices.

2.4 Reduction of balancing energy

Another possibility for DSM is the reduction of balancing energy demand in a balancing group. The "Ökostrombilanzgruppe", a balancing group responsible for the fluctuating renewable energy production, isn't exactly predictable when it comes to production. This unpredictability often leads to a certain demand of balancing energy, which is paid by all customers. The balancing energy needed could be reduced by the coordinated reduction of demanded power from the companies in the EDSL-program, resulting in a cost reduction for everyone. On the other hand during times of predicted green-power production commodities can be produced at low prices. Additionally through building a pool of industrial electricity consumers, the short peak in balancing energy demand can be absorbed to a certain degree by the use of DSM.

2.5 Grid congestions and emergency situations in the grid

Often the saturation of the demand is not an issue when it comes to generation capacity, but the problem is the transportation of the energy. A method to avoid grid congestions is redispatch, where the power plant schedule according to the market is altered, leading to a less cost efficient use of power plants. This method leads to new costs, so called redispatch-costs. These can be minimized through the use of DSM if it is possible to avoid congestions through the use of DSM and the companies capable of providing DSM for redispatch-purposes are taken into consideration. Another grid situation which could be prevented by the use of DSM is the danger of a blackout. A blackout can occur if the sum of the actual generation can't saturate the actual demand or an infeasible net situation occurs. This results in a frequency drop throughout the entire grid. If the situation of a frequency drop occurs, the control mechanism described above (primary control reserve …) are activated. If those mechanisms can't provide enough power or fail otherwise the frequency drops even further until the point is reached where electrical machines go off the grid to prevent damage to themselves. Resulting in a breakdown of the electricity system, a so called black out. In such extreme situations contracted companies can drop their load to prevent black outs and therefore provide additional safety to the entire grid, or at least bigger parts of the grid.

3 Versions of DSM-measures

As shown in Figure 1, there are different possibilities how an industrial company can implement DSM. It is necessary to mention that the most important requirement is that the DSM-measure won’t affect the output of the entire production cycle.

3.1 Temporal load shifting

The most common and easiest method for load shifting is ripple control. But since this is no inner-industrial method it won’t be discussed any further at this point. Next to ripple control the voluntary load dropping of customers is a method of direct load reduction. The chronological activation of DSM-measures is a method to counter grid congestions even though these measures can under certain circumstances result in extremely high costs for the company.

Most industrial companies don’t show significant consumption peaks but rather flat day/night-consumption-characteristics. This means, that a load shift can only be interpreted as a delay in production. This can be seen a possibility for the company if the current order situation is bad. In some rare occasions the gain through selling the commodity can be less than not producing it and selling the saved energy.

The potential for DSM is especially high in energy-intensive industry branches. Industry branches qualify for load shifting due to their structure. In comparison to small customers or business-customers, industrial customers have a higher total consumption separated amongst many switchable machines which can be used for load shifts. A detailed analysis of the production schedule needs to be made in order to evaluate the DSM-potential of a certain company. In some companies machinery with a very high specific demand can be found such as electric arc furnaces, which can be switched off for a short period of time. Taking energy service storage into account the potentials for DSM can be raised even further in certain companies. Other methods of reducing or shifting loads is to change the production plans, which is only possible for companies not working on 3/3 shifts, as well as the temporary shutdown of the entire production. The two methods discussed are to be seen as very expensive due to the loss in creation of value. Additionally technical issues, such as start-up and shut-down times of machinery have to be taken into consideration when investigating the use of DSM. The potential and willingness to participate in short term production disruption is likely to be higher in companies with a currently bad order situation.

3.2 Energy service storage

A cheap and easy method for consumer sided load management in industrial companies is using energy service storages. These will be explained on basis of some examples. Excluding production processes such as electric arc furnaces, electrical energy is rarely directly used. In most cases it is used for a service, the so called “energy service”. Electricity is used to create services by either transforming it into another form of energy (such as cooling, creating air pressure, lighting) or in production processes where a certain good or material is brought from one form to another (for example grinding, reforming, shredding and so on). The newly created commodity can then be used by a follow up process. As example, breaking up rocks can be the energy service in a quarry, the resulting crushed rocks can be stored for further use. The storage itself functions as energy service storage. Another example would be a refiner, which is used in the paper industry for creating wood fibre out of wood chips. The demanded energy for this process depends on the quality of the fibre, but can range from 1 to 2 kWh per kilogram of fibre, which makes this process very energy intensive. The power-demand of such a refiner can sum up to several MW. As it was the case for creating crushed rocks, the fibre can be stored for later use.

Through the possibility of storing energy services, energy consumption can be decoupled from the time the commodity itself is needed. Instead of storing electrical energy the energy service is stored. Such storages are common in certain industries because different parts of the production cycle need different times for production of the corresponding good. Almost all production chains have a limiting link, which slows down the whole process, as can be seen in Figure 5. This is often the case because this part is described by extremely high investment costs in comparison to the rest of the production chain. While the limiting part of the process is permanently running, other parts of the production are temporarily on halt due to overcapacity (Gutschi & Stigler, 2006).

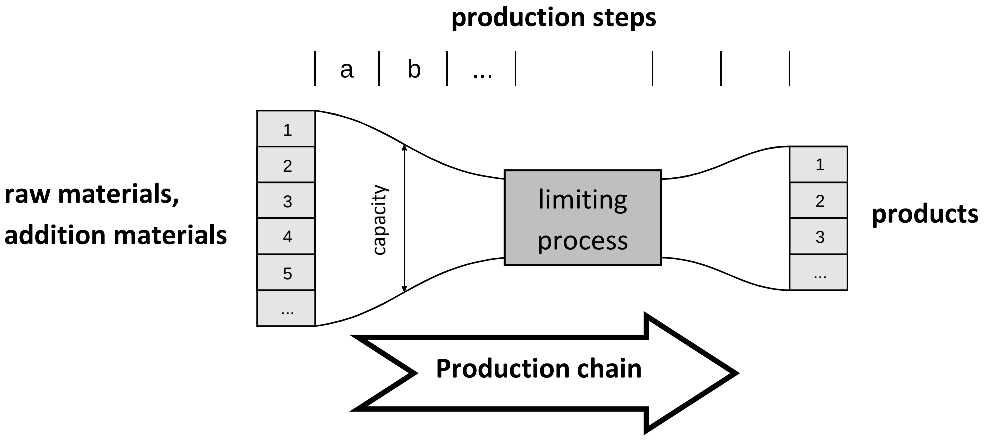

Figure 5: Symbolic representation of different production capacities in a production chain (Gutschi & Stigler, 2006)

In most cases storages are installed throughout the production process to prevent a shutdown of the entire process cycle from a malfunctioning machine. For example, it is necessary to keep a rotary kiln running continuously whereas the parts of the process before and after the kiln can store their corresponding products. Through the efficient use of the commodity storages as energy service storages load shifts can be achieved, resulting in a reduced peak load. As a result we see an organisational method to prevent peak loads. It has to be said at this point, that companies will only participate if there is a certain financial benefit resulting from their actions.

3.2.1 Circumstances promoting or demoting energy service storages

If peak load management can be achieved through energy service storages depends on many different factors, which mainly influenced by the branch of the company. But there are also company-specific conditions, such as configuration of the equipment or the organisational configuration of the company as well as the economy, spatial and social environment. See (Gutschi & Stigler, 2006).

Positive effects on DSM through energy service storages:

- Storable products or semi-finished goods
- Possibilities of storing goods during the production process at reasonable costs

- Partial overcapacities in the production cycle or low capacity utilisation of certain parts of the production equipment
- Possibilities of short term production disruption
- Little or no production during weekends or night time
- Production of commodities with little time pressure or innovation pressure
- Order situation below average

Negative effects:

- Production process organized to demand only base load
- Coupled products which result of originally storable products, which will be used in latter products with low efficiency
- Good order situation due to good economic situation
- Environmental restrictions like noise protection
- Collective contracts which prohibit a transition to flexible working hours
- Branches where costs for electricity demand make up only a small proportion of the entire costs
- Goods with high deadline pressure
- Perishable goods like food or pharmacy-products
- Materials which need instant processing
- A lack of general knowledge of how to change production processes

3.3 Increase of production from customer generation

The opposite way of managing load is by increasing customer generation. This can be done by increasing the power of the generation to its maximum at those times when there is no need to have the generator run at full capacity. Such situations may occur during times of high peaks because at these times the prices are high enough for this method to pay off.

3.4 Activation of backup generators

Backup generators function as safety-equipment in manufacturing companies or in hospitals, where a disruption of the power supply simply isn't acceptable. As for manufacturing companies, examples would be the automobile production, electronics or the chemical industry. Additionally cement production needs undisrupted power supply for its rotary kiln as long as it is hot If power supply would fail the kiln would deform due to the heat and high mass. This would then lead to massive costs. This capacity of backup generators can be used if they can be activated from outside the company. Considering the fuels needed to operate these generators there should be no boundary to the use of backup generators. Another benefit arises from using backup generators for power supply, if the generator is needed in the company itself, it is already running so the start-up time is reduced to zero. Additionally through the constant use of the backup generator the overall efficiency rises and the owner constantly receives information about the current condition of the generator. Considering these facts, the backup generator will get more economic.

3.5 Controlling the use of DSM-Measures through comparison of scheduled load and actual demand

According to the law a schedule is the precise information about the timetable of demand and production, meaning that the average load value for generation and demand will be built for each period of measurement. A balancing group on the other hand is a virtual fusion of customers and suppliers to a group where there needs to be a balance between generation and consumption.

All members of the balancing group need to tell their schedule for either demand or generation between one to thirty days before the actual generation or demand do occur to their corresponding head of the balancing group. If there are short term deviations, changes to the schedule can be made on basis of quarter hours. The schedules for every balancing group will then be given to a balancing group coordinator, which has to give the information on basis of a quarter of an hour to the control zone manager if demanded. Who can then use this information gathered to ensure system stability. If a deviation occurs, balancing energy will be required, and if there is a contract with a company regulating the use of DSM, the control zone manager can verify if the contracted company participated according to their contract.

4 Potentials for customer sided load management in Austria's industry

There are different reasons qualifying industrial companies for DSM measures. On the one hand equipment with a high consumption could be switched off or the time of their use shifted, on the other hand customer generation or backup generator could be used.

4.1 Technical potentials in the industry

Especially equipment or companies showing a high peak load qualify for DSM. Table 3 shows some industrial sectors which qualify for DSM thus having a high potential. A high consumption alone does not necessarily mean that peak load management can be applied. So each company has to be tested, considering the individual situation, in order to evaluate the potential for DSM.

Table 3: Processes and equipment with high power input in different branches

Branch	Equipment with high demand	Barriers
Oil and chemistry	Electrolysis, electro-chemistry, condensers, pumps, stirrers, blowers, cooling aggregates, air liquefiers, stationary engines	
Rubber and plastics	Industrial furnaces, condensers, pumps, stirrers	
Paper and fibre	Machines for pulp wood and paper, pumps, condensers, blowers, backup generators, hocks	Partially long start-up times
Iron and steel	Steel-mills, electric arc furnace, curing oven, annealing furnace, induction hardening, pan furnace	
Agriculture and forestry	Stationary engines, blowers, engines work on discontinuous basis, IR-heating lamps	DSM effective only in case of large concerns; spoilable goods
Non-iron metals	Electro-chemistry, electric furnaces, thermal treatment furnaces, induction hardening, steel-mills	
Trade	Ovens, cold store, air-conditioning	Low power, spoilable goods
Gastronomy and hotel business	Air-conditioning, lighting, canteen kitchen, cold stores, washing machine	Spoilable goods, energy service is part of the product
Ironware	Induction hardening, electrically heated ovens for temperature treatment, steel-mills, engines for mechanical treatment, galvanisation	
Stone and earth	Industrial ovens, breaker mills, mills, grinders, mixers, micro strainers, blowers , drivetrains for rotary kilns	
Food	Pumps, condensers, stirrers, cooling, washers	Spoilable goods
fabrics	Stationary engines, dryers	
Wood treatment	saws, compactors, blowers, dryers	
Vehicle construction	Industrial ovens, backup generators, pressurised air	
Engineering	Stock removing machinery, presses, steel-mills, laser cutters	
Infrastructure and supply	pumps, condensers	
electronics	Air-conditioning	Sensitive production equipment
mining	Breaker mills, steel mills, micro-strainers, (percolating water-)pumps, blowers, charging of electric vehicles	

Lumber mills, composite panel industry	presses, wood chip machinery, saws, blowers	
Glass and ceramics	Electro ovens, backup generators	Glass melt must not cool down
Foundry	Electro ovens, steel-mills	Delays in heating must be short (30 min)
Meat market	Cold stores	Spoilable goods
Paper processing, print and graphics	Printing press	High deadline pressure, low power
Milk products	cooling	Spoilable goods
bakery	Electrically heated ovens, cooling	Spoilable goods, deadline pressure
Construction industry	mixer	Concrete must be processed quickly
clothing	Washers, dryers, looms, electric irons	Low power
mills	Crushing mill	
households	Night-storage heater, domestic hot water tank, heat pump	

Not all the companies or industrial sectors qualify equally for DSM measures. Table 3 should only give a good overview over the numerous possibilities.

The potential of some promising industrial consumers and branches will be described in the following subchapters. Other further information is given by BRIMATECH. Notice that only some examples of promising industries are shown. To get an overview about the potential in a specific company you have to identify the process flow in detail. Therefore we have no figures of the potential, but qualitative analyses of possible machines or processes. The following points are based on (Gutschi C. , 2007).

4.1.1 Potential of cement industry

The cement industry does have one of the most promising potentials for DSM. The best fitting application for the cement industry may be the peak load reduction. The production of cement needs, depending on the quality, lots of electrical energy but some steps of the process can be stored easily. Figure 6 shows a typical process flow in the cement industry. As can be seen the limiting process is the around the clinker production. The steps before and after that can store their products. The main problem in the cement industry is that most of the production sites do have very small stocks. There was no need to store semi-finished goods when the production sites where plant. Now it's not as cheap to install stock as if it would have been plant under construction. But an analysis of TU Graz (Gutschi & Stigler, 2006) led to the result that specific costs for building storages in the cement industry is cheaper than building a new plant. The calculation does have some boundaries which can be read in the paper. The only constraint which has to be proven for each industrial site is if the grinding capacities are enough to produce in stock.

The high potential of the cement industry got early identified by Yorkshire Electricity (1996). In cooperation with 13 cement sites 110 MW negative capacities got collected which was used for frequency control. This shows the potential of the cement industry and its possible fast response to a call for reducing their demand (Hull) (IEA).

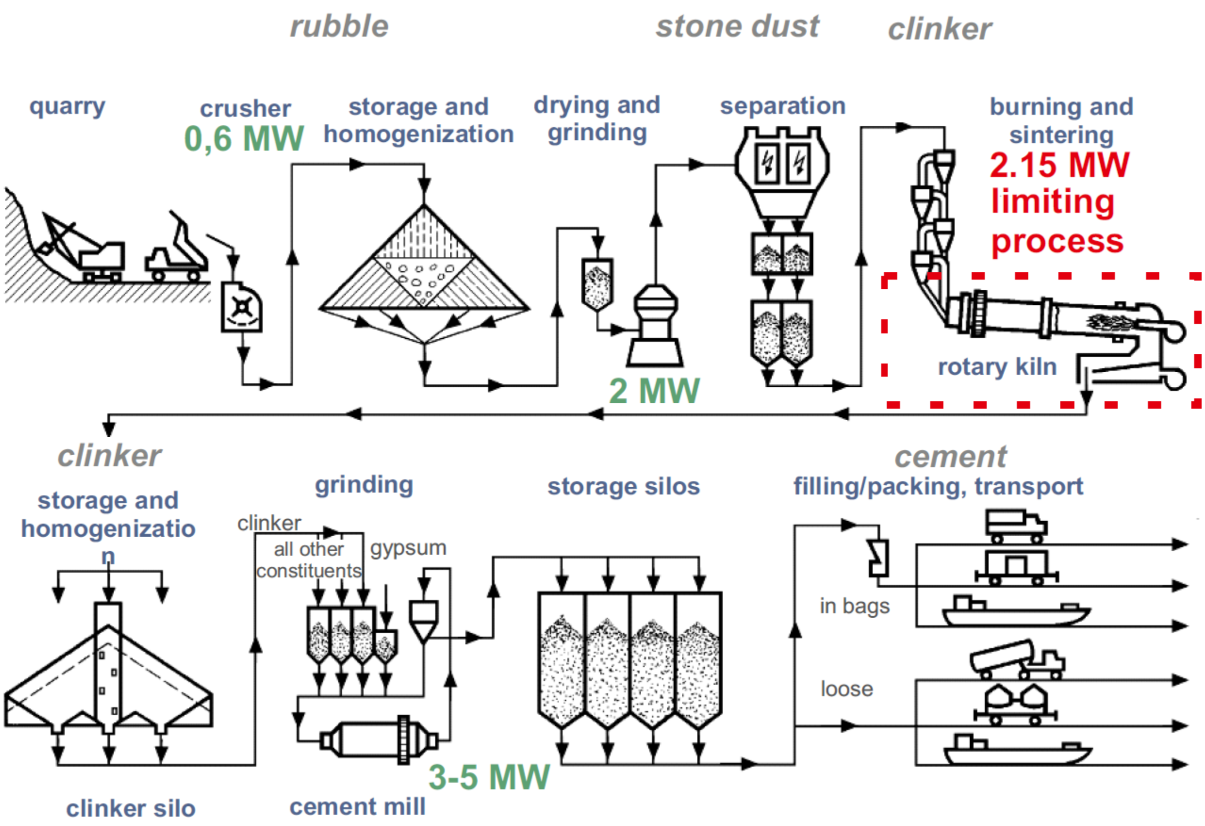

Figure 6: Basic process chain in the cement industry (source: based on (VDZ- Verband deutscher Zementwerke, 2005))

4.1.2 Potential of paper industry

Another promising industry is paper and pulp cause of the big machines which are used there. In Austria about 500,000 t of paper is produced per year. This production leads to an energy demand of about 600-700 GWh and a capacity peak of 90-100 MW. A high amount of the needed electrical energy gets generated in directly at the industrial site by power-heat cogeneration. Wood grinder and refiner do have the highest potential in the paper industry. A typical wood grinder does have demand of 3-5 MW. This was confirmed in our interviews as well. One industrial site does have about five of these wood grinders. Refiner does have a demand of about 15 MW. These energy intensive machines bring much better results in producing wood fibres than chemical solutions, but also need more energy. The wood fibres already get stored cause if there is a problem with the refiner or wood grinder the production of paper can't stop. Therefor a storage is installed which could be used for DSM. The storage of those fibres is limited to about 24 h. If they get stored for a longer time, there is a loss in quality and the paper may don't get white (Gutschi & Stigler, 2006). The time where those fibres could be taken out of the storage is far long enough for all possible applications of DSM.

4.1.3 Potential of stones and earth industry

As can be seen from Figure 7, the stone and earth industry counts to the most energy intensive branches in Austria. Another positive effect for DSM in this branch is that there are some big machines which can produce more than instantly is needed for production. The overproduction can be stored in a hopper so that the limiting process runs all the time. The smaller the stone pieces are which are produced, the higher is the need for energy and capacity to get it. Especially the cement and chalk production are energy intensive. The most Mills and breaker mills do need the most power in the stone and earth industry. But also separator, sieves, band-conveyors and blowers need lots of energy. These are normally machines without much electronic parts, so they can switch on and off easily nearly without preparation time. Energy costs are a major part of the production costs in this branch. Therefor the application as peak load reduction, where the energy price is high, could be the best fitting application for the stone and earth industry. In the winter period there often less need for stones and earth, so the capacities can be shifted in this time of the year where prices are high. That the capacity isn't used to capacity can also be seen in Gutschi (Gutschi C. , 2007). Over the whole year the energy consume of stones and earth industry is the opposite of the general demand. There we have peaks in summer and less demand in winter. This is because of the building sector, which is weaker in the winter period. With little costs storage silos can be build which can help to save a lot of money for the company and help to keep the electricity system save and cheap for all consumers. In some cases not even a storage building is needed. Products can be stored simply on ground, so that space is the only thing needed. The bigger the product the easier the storage, because small parts shouldn't stick together. The demand in this sector isn't as high as for example in the paper industry, but reasonable for DSM measures.

4.1.4 Further possible potentials

The easiest way to get potentials in the industry is to look where due to historical reasons overcapacities are installed. Even if the process steps with installed storages have not a great potential itself, the aggregate of lots of such processes can have an effect. The main aim of EDRC project is to find potentials of different ranges and combine them to one sellable product. In some cases also the installation of storages in an effective process chain can help to reduce the energy costs by an amount which justifies the storage. New industrial sites normally are optimized to have a great number of use hours, where DSM makes not as much sense as by existing equipment.

4.1.4.1 Chemical industry

There are several possible processes in chemical industry that could fit for DSM. For example the Chlorine-Alkali-Electrolysis has a high potential because of the energy intensity of the process and the ability for fast response to a call. There are three different methods of Chlorine-Alkali-Electrolysis and all of them are energy intensive. There is not the greatest potential in Austria, but in Europe several sites could help to keep the system safe by delivering control energy. Another possible application is the production of Calciumcarbit.

4.1.4.2 Iron and steel

In iron and steel industry the most energy intensive applications are electric ovens especially arc furnaces. The electric power of arc furnaces is about 30 to 40 MW. These devices can be switched on and off easily with respect to downstream processes. By shifting maintenance there is a high potential to switch these ovens within the week. A constraint in this case is that the oven is not needed all the time, so the capacity is not used 100 % of time. If this is given, the production loss is higher than possible earnings with DSM.

Even electrolysis processes due to producing non-iron metals like copper and zinc and galvanic processes do have a significant potential for DSM. As already mentioned the industrial site should be visited in such cases to find out how much potential is available for what range of time.

4.1.4.3 Production of technical gases

The element breakdown of air in its main parts azote, oxygen and argon is energy intensive. The first step is to clean the air from contaminant like dust or carbon dioxide. The cleaned air is set under high pressure of about 200 bar and gets cooled down to -193°C before it gets rectified. After that the elements are stored as a fluid in tanks. These tanks could be used as storage and would be a good chance to use DSM. Big sites do have a need for power of about 10-15 MW, which means they have enough potential for industrial DSM.

4.1.4.4 Compressed-air system

Many industrial processes need compressed-air. This process can cause up to 25 % of the energy use of a company. Normally a compressor puts air in a vessel and by putting more and more in the air gets compressed. Normally these vessels are oversized so the compressor only works 50 % of the time. If the companies are able to charge the vessel in times of low load and use the stored air in peak load times it would be an easy way for DSM. You can get a reduction of the energy costs and help that the system does not need as much power plant in peak hours. Another positive effect of this is that the operating cycles decrease which may leads to longer lifetimes of devices. Another possible application is to use these compressors for control energy because of the fast response and the normally big variation time. So if there is an intelligent control system, compressed-air systems could be used for positive and negative control energy with really low response times.

4.1.4.5 Cold air storage

The use of air conditions in large scale and also in small scale for domestic use can be seen as a potential for DSM. If cold air is produced in a large effective industrial site and stored there. The cold air can be transported in pipes like heat in winter. The storage gets his load in off-peak hours and gives it to industrial or domestic users when they need it. Even in large companies where the air condition needs more than 1 MW power the potential can be seen as high enough.

These are just some of much possible potential for DSM in industry. Every big industrial site has to be visited and individual decisions for DSM measures have to be done.

4.2 Overview over the potential in different branches

A high demand in electricity of a branch or energy-intensive processes is a hint that DSM measures can be applied well. It is to be expected, that the effects are stronger in larger companies in comparison to smaller companies.

The highest incentive for customer load management can be found in branches where the costs for demand of electricity make up a big part of the entire production costs. This can be described by the proportion of electricity demand to gross value added or production value.

Figure 7 shows the electricity demand for each unit of gross value added[1] for most economic branches in Austria. Due to the financial crisis, leading to non-representative results, the year 2007 (one year prior to the crisis) was picked as it shows the unadulterated conditions in the industrial sector. The figure shows the typical electricity-intensive branches such as mineral-oil processing,

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[1] According to Statistik Austria, the gross value added is a measurement for the economic output of a company or a branch and includes the sales revenues incl. subventions not including intermediate inputs, taxes and dues

paper and card board, iron and steel, mining, stones and earth as well as chemistry, as those industries are the ones with the highest specific use of electrical energy. After the branches energy-supply/district heating-supply, which can't be used for load management, the branches glass, ceramics and cement as well as rubber and plastics, are those branches where potential for customer load management exists. Additionally DSM can be of use in connection with energy service storages, in some not so energy intensive branches, but in this case the branch itself needs to be properly investigated.

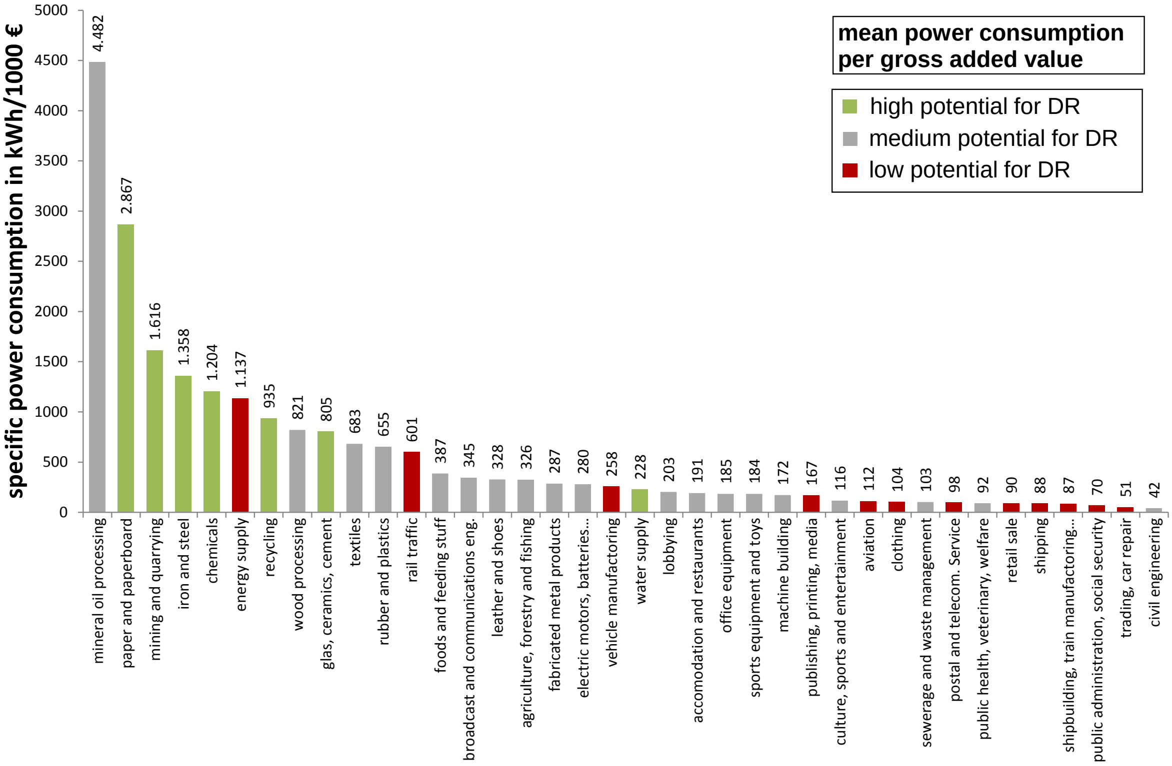

Figure 7: Estimation of the electricity intensity of Austria's economic branches in relation to their gross value added for the year 2007, numbers on basis of data from Statistik Austria

To analyse the efficiency of energy service storage the value added in a company as well as the intermediate inputs need to be considered, summing up to the gross production value[2]. To investigate the aspect of tied capital, Figure 8 shows the average specific electricity demand as a quotient of the used electrical energy and the production value for most economic branches in Austria. This figure confirms which was said about using energy service storages.

In regard to energy service storages the following branches are of high importance:

- Paper and card board
- Mining, stones and earth
- Iron and steel
- Chemistry

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[2] According to Statistik Austria the production value can be calculated on basis of the sales revenues, the activated internal labour, the acquisition of for resale intended goods or services as well as under consideration of the supply change of done and undone products an commodities as well as services which are intended to be resold.

- Glass, ceramic and cement

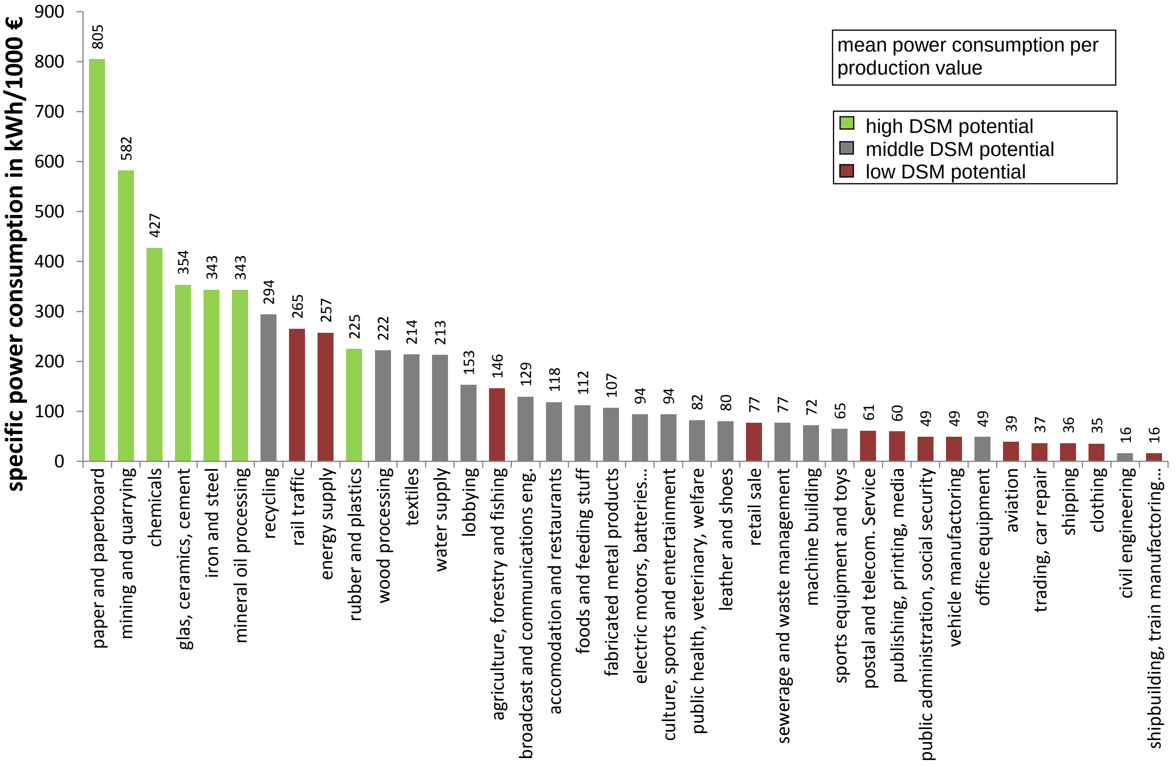

Figure 8: Estimation of the electricity intensity of Austria's economic branches in relation to their gross production value for the year 2007, numbers on basis of data from Statistik Austria

Chapters 4.3 and 4.4 show those Styrian and Upper-Austrian companies with the most relevant DSM-potential. These provinces were chosen by the project manager, Mr. Korsitzke (cybergrid). Due to the fact that many energy intensive industries from many different branches reside in these two provinces the potential for all of Austria can be derived from the results. Another factor for choosing only two provinces was that for this study only a limited amount of time was provided.

From Figure 9 the potential for DSM per sector allocated from interviews and up scaling. Because of less knowledge and interviews the sector stones and earth has a little potential, but we predict that if DSM measures get more popular, the potential in this sector will be far higher.

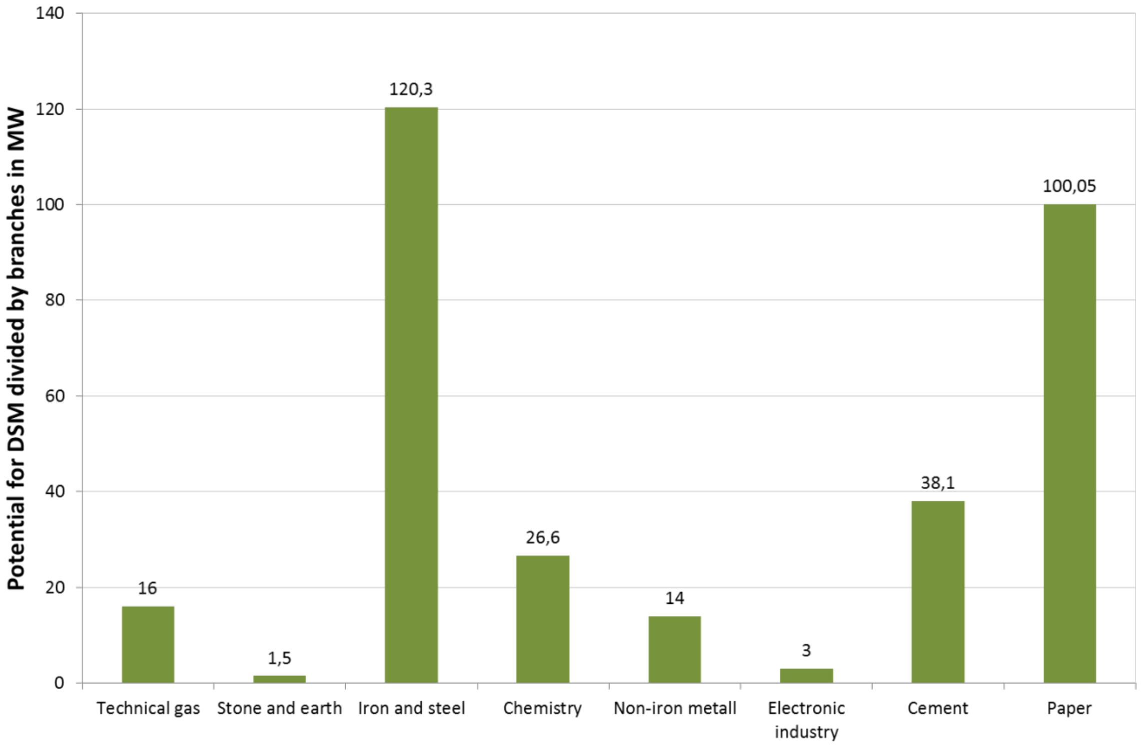

Figure 9: Overview of the potential distribution to different branches. Data combined from interviews and up scaling.

4.3 Relevant Companies in Styria

Styria itself has always been an industrial-region. Especially the region of Upper-Styria has a high amount of heavy industry. With approximately 1400 companies this region accounts for as much as 15 billion Euros. This sums up to 37% of the gross domestic product of this region and to about 18 % of Austria's total industrial production (2006). Figure 10 shows the 68 biggest Styrian industrial companies categorised by branch.

The most energy-intensive branches in Styria are:

- Paper industry
- Metal production and processing
- Stones and earth
- Cement industry
- Engineering and vehicle construction

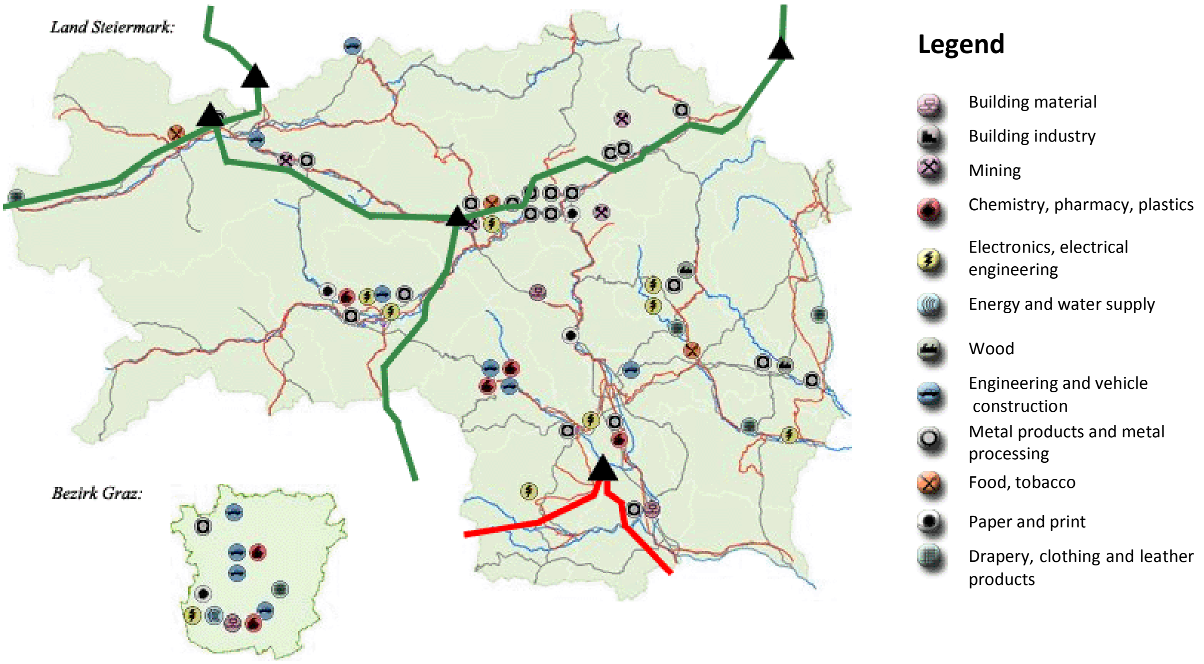

Figure 10: Overview over the 68 biggest Styrian industrial companies, categorized by branches (IV Steiermark und Wirtschaftskammer Steiermark, 2006)

Figure 10 shows the most relevant companies when it comes to DSM-potentials in Styria, categorised by branch.

Table 4: Overview over the most relevant companies qualifying for DSM

Paper	Stone and Earth	Cement	Metal production and products
Sappi Austria Produktions-GmbH and Co KG	Wolfram Bergbau- und Hütten-GmbH NFG KG	Wietersdorfer und Peggauer	Böhler Schmidetechnik GmbH & Co KG
Mayr-Melnhof Karton GmbH & Co KG Werk Frohnleiten	RHI-AG (vormals Veitsch-Radex)	Lafarge Perlmoser	BOEHLERIT GmbH & Co KG
Norske Skog Bruck	VA-Erzberg-Gesellschaft	Klöcher Basalt Werke	Böhler Edelstahl GmbH
Zellstoff Pöls AG	Porzellanfabrik Frauenthal GmbH	Schotter und Betonwerk Karl Schwarzl Betriebsges.m.b.H	Böhler Bleche GmbH
		Pronat Steinbruch GmbH	voestalpine Austria Draht GmbH
			voestalpine Bahnsysteme GmbH voestalpineStahl Donawitz GmbH voestalpine Tubulars GmbH & Co KG Alpenländische Veredelungsindustrie (Marienhütte) Andritz AG Magna-Steyr-Fahrzeugtechnik

4.4 Relevant companies in Upper Austria

Major electricity consumers in Upper Austria are the Voestalpine AG, the fibre producer Lenzing AG as well as the aluminium processing company Austria Metall AG and Austria Alu Guss GmbH in Ranshofen. Due to the complicated process-structure of the Lenzing AG, this company’s potential for DSM is rather small. Considering the size of Voestalpine AG, it has to be assumed, that their energy management potential is well used and therefore the resulting potential for DSM would be rather small.

The most relevant companies, according to their DSM potential, are shown in Table 5 and are categorized in the corresponding branches.

Table 5: Overview over the most relevant companies for DSM purposes in Upper Austria

Paper	Stones and Earth	Glass, ceramics and cement	Metall production and products
UPM Kymmene Austria GmbH	Salinen Austria	Gmundner Zement Produktions und Handels GmbH	voestalpine AG
SCA Grapic Laakirchen	Poschacher Natursteinwerke GmbH & Co. KG	Eckelt Glas GmbH	Austria Metall AG
Nettingsdorfer Papierfabrik AG & Co KG	Schärdinger Granit Industrie AG	Kirchdorfer Zementwerk Hofman GmbH	SAG Euromotive GmbH & Co KG
Tann-Papier Ges.m.b.H.			Amag rolling GmbH
Chemistry			Amag extrusion GmbH
Lenzing AG			Austria Alu-Guss GmbH
			MEPURA Metallpulver GmbH
			Miba AG
			SGL Carbon GmbH & Co

4.5 Experiences on basis of discussion with industrial companies

To gain experience considering the willingness to discuss as well as their general incentive for DSM measures and test the developed questionnaire, interviews between TU Graz, Brimatech and relevant companies were held. Because of data protection no company names will be mentioned at this point.

These interviews resulted in the information, that due to the very intense competition and the ever rising energy- und economy awareness and also because of the financial and economic crisis; the general awareness for efficient and economic use of electrical energy is getting stronger. The companies interviewed gave a positive feedback on the project EDRC.

The companies try to use their process-cycles and energy-consumers or customer generation at highest logistical and economic efficiency. The more production processes make up the cycle the smaller the incentive of a company to accept controlled load shifts. The incentive to accept load shifts is higher if the company can perform them themselves at times of need, for example if a shift is needed the company will receive a call. This ensures that companies still got full control over their production cycles. Also the acceptance for less frequent but longer lasting shut downs is higher than for more frequent shut downs with shorter durations. This shows that the potential for peak load reduction is higher than for balancing power supply.

The rules for load management are known to the participants. Primarily peak load guards for a reduction of grid costs are being used. Very large energy consumers nowadays already have an appointee for load management who actively participates on the day-ahead electricity market and even on the balancing energy market. These companies therefore show a reduced potential for participating in the EDRC program. Higher still unused potentials can be found aside the paper and steel industry for example in energy intensive medium sized companies.

Due to the many variations of production equipment in each company, a comparison of different companies even in the same branch is very difficult, calling for an individual concept for each company. A rather large uncertainty factor for companies is the punishment if the arranged measures regarding DSM cannot be fulfilled. It is absolutely necessary for each company to know the consequences in advance and if it’s possible to avoid punishment by pooling up. The idea of pooling up with other customers was well received.

If the company has a good order situation there is rather little incentive to risk production output because of load management, even if it would be possible.

Ensuring minute-precise ramps while changing the load will be hard to achieve or rather impossible from a technical angle of view. A predefined change of the average power demand in 15 minute periods seems to be easier to realise.

Another barrier is the complexity of the process including the balancing group itself. The rules and correlations in a balancing group need to be explained to the appointee for energy management participating in the EDRC program, in order to ensure success.

The conclusion of those two “test-interviews” can be summarized as follows. The incentive to participate in DSM measures basically exists, but you have to consider all the aspects of every company anew. Additionally it is of utmost importance that the idea and rules behind the EDRC program are communicated in a more than sufficient manner.

Further interviews were held by Brimatech, CyberGrid and APG with promising companies which partly signed a letter of intent. These results are shown in detail by Brimatech.

5 Description of the simulation model ATLANTIS

ATLANTIS is a techno-economic model of the electricity industry in Continental Europe (former area of the UCTE) – a synchronous area with a net installed capacity of about 750 GW by the end of 2011 and annual consumption of approximately 2,600 TWh in 2011 (ENTSO-E, 2012). A major part of the scenario model is a database of the most important facilities and companies in the investigated area.

Based on the comprehensive database, ATLANTIS is a simulation model which is close to reality in technical matters but is also able to give an explanation of the economic behavior of electricity markets. The technical part of the model includes all necessary elements of the physical system, e.g. the synchronous transmission grid (400 kV and 220 kV levels), about 10,000 existing individual power plants as well as final consumption of electricity geographically downscaled to about 2,500 grid nodes.

The economic part of the model covers electricity trade by using market models like net transfer capacity (NTC) based zonal pricing and a European-wide market coupling between countries, as intended by the European Union. Major European power producers are described by simplified balance sheets and income statements.

5.1 Global input parameters

In addition to the master data which represents the Continental European electricity system until today, future scenarios up to 2050 can be built by adding projected or fictitious power plants, transmission lines, transformers and grid nodes. In the course of this project, about 10,000 additional power plants have been modelled, which either replace existing units at the end of their operation, or offer additional production capacities (especially in case of renewable energy sources). These supplemental units are sited in locations of units which are replaced by them or, in case of RES, in locations of appropriate potential of primary energy sources.

Besides the physical parameters included in the modelled power plants, transmission lines and transformers as well as final consumption, economic parameters and market data have to be considered within the simulation. These parameters include assumptions for future fuel prices, CO_2 price, inflation, NTCs, investment costs, learning curves, operation and maintenance costs of power plants and many more.

5.2 Assumptions of energy and environmental policies

To define all those input parameters needed for a scenario simulation using ATLANTIS, certain developments regarding energy and environmental policies have to be assumed. For the EDRC project, a “green” scenario was chosen to show the effects of DR measures like reduction of CO_2 emissions even at a high level of renewable generation in the electricity system.

The assumed scenario’s main target is to reduce CO_2 emissions by forcing renewable energy sources in the electricity generation mix, and by simultaneously decreasing fossil generation capacities. The actual development derives from the 450 ppm scenario of the World Energy Outlook 2010 (International Energy Agency, 2010).

Another target of the European Union which is represented in this scenario is to reach higher end-user efficiency. This is represented by a rather slow demand growth until 2030, compared to actual growth rates. Countries in Eastern Europe will experience a rather strong growth of economy and average wealth leading to a higher demand. Due to this, the Continental European total demand of electricity increases in this scenario.

Both generation capacity and peak load increase in this scenario. The proportion of renewable energy sources for electricity production is increasing and the absolute as well as relative amount of thermal generation capacity is decreasing, thus satisfying the general idea of the 450 ppm scenario. The generation capacity almost doubles between 2006 and 2030, reaching a total of more than 1,000 GW.

The price for oil is also based on the 450 ppm scenario of the WEO 2010 (International Energy Agency, 2010). The oil price experiences an increase until 2020 where its peak is reached. From there on the price stays the same until 2030. This development can be explained by the general rethinking process towards a more eco-friendly environment, which this scenario is based on, leading to a reduction of fossil fuel demand, thus resulting in lower oil prices.

5.3 Program flow

Figure 11 shows the flow chart of a scenario simulation. Based on the predefined scenario, the calculations are performed on an annual and, respectively, monthly base. Every month is furthermore divided into a number of peak and off-peak periods. The monthly load duration curve is discretized by the means of the corresponding periods. At the beginning of every simulated year, the calculation starts with a system adequacy check for winter and summer peak load, which also considers physical load flow restrictions. The physical load flow is calculated using a DC-OPF (DC optimized power flow) algorithm. In this initial step, the model proves whether the simulated electricity system is able to handle the annual peak load hour. If not, the model automatically builds a new gas-fired CHP plant to cover the missing generation capacities, using an “optimal” placement algorithm. This step is repeated until the amount of generation capacities is sufficient, and no lines are overloaded.

In the next steps, the dispatch of power plants is calculated by minimizing the total generation costs, using different market models. More precisely, a zonal pricing algorithm under consideration of net transfer capacities (NTCs) at cross border lines is applied, followed by a DC-OPF calculation to proof whether the market results can be realized without violating the (n-1) criterion[3]. In case of a violation, power plants are redispatched to resolve the limiting congestions, still trying to keep the total generation costs as close to the optimal dispatch as possible.

Fluctuating generation like hydro power or wind power is considered by the long-term average generation in the particular month. A power exchange where the modeled companies trade generation surpluses is calculated parallel to the dispatch. When the utilization of the power plant park is determined, fuel demand and CO_2 emissions of each period are calculated.

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[3] The (n-1) criterion is evaluated by reducing the thermal limits of all transmission lines to 70 %, which is generally known as a good approximation.

Finally, the required retail price of electricity for each country is calculated considering “second best” regulation. The dynamic simulation of different scenarios over time shows the effects of changing climatic conditions on power production, electricity exchange and network utilization.

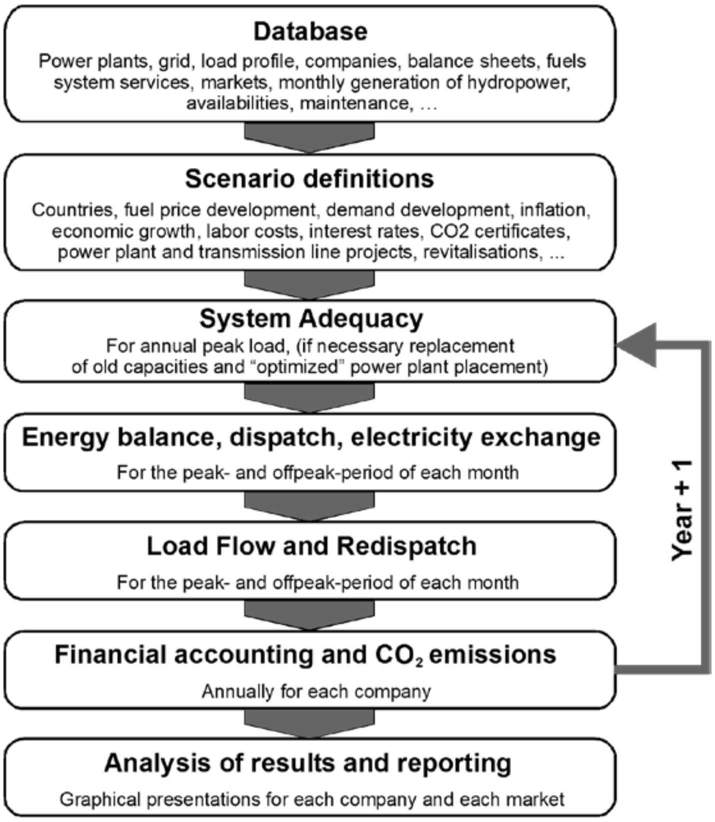

Figure 11: Flow chart of the ATLANTIS scenario model . source: (Gutschi, Jagl, Nischler, Huber, Bachhiesl, & Stigler)

5.4 Adjustment of ATLANTIS for project EDRC

To be able to simulate effects of demand response, some additional functionality has to be added to ATLANTIS. Final consumption of electricity is one of the major components in the electricity system. Due to this, hourly load curves per country of 2006 (ENTSO-E, 2012) have been implemented in ATLANTIS to represent the behaviour of end customers as good as possible (for example, see Figure 14 on page 32). Duration curves are derived from these hourly load curves and discretised to reduce simulation time. To be able to consider effects especially in times of highest loads, a peak load period containing 10 % of the highest loads in every month has been simulated in addition to the usually simulated periods[4]. The development of electricity consumption is modelled by scaling the load curve of 2006 by the factor of increasing or decreasing annual demand.

To consider DR on an hourly basis, a mechanism to include hourly changes in electricity demand has to be implemented into ATLANTIS. Therefore, a tool to include the statically assumed DR measures (see chapter 6.2.1) has been introduced for this project. Because the load curve of 2006 is statically implemented in ATLANTIS, there is no need to integrate DR measures in ATLANTIS dynamically.

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[4] Usually the load curve is divided by a ratio of 30/70 for peak times and 80/20 for off-peak times in accordance to time.

Final demand is simulated in an aggregated way, considering that distribution grids are constructed in radial topology and connected at their roots to grid nodes of the ultra-high voltage transmission grid. Thus, the underlying distribution grids can be abstracted by connecting all power plants directly to transmission grid nodes and by concentrating the final consumption within the distribution grids to a total demand per transmission grid node. While the assignment of electricity consumption to grid nodes is based on population densities for the common final demand, a new assignment has to be found for DR measures in application case one (chapter 6.1). In application case two (chapter 6.2), the total DR potential is concentrated to only one grid node, depending on the simulated showcase.

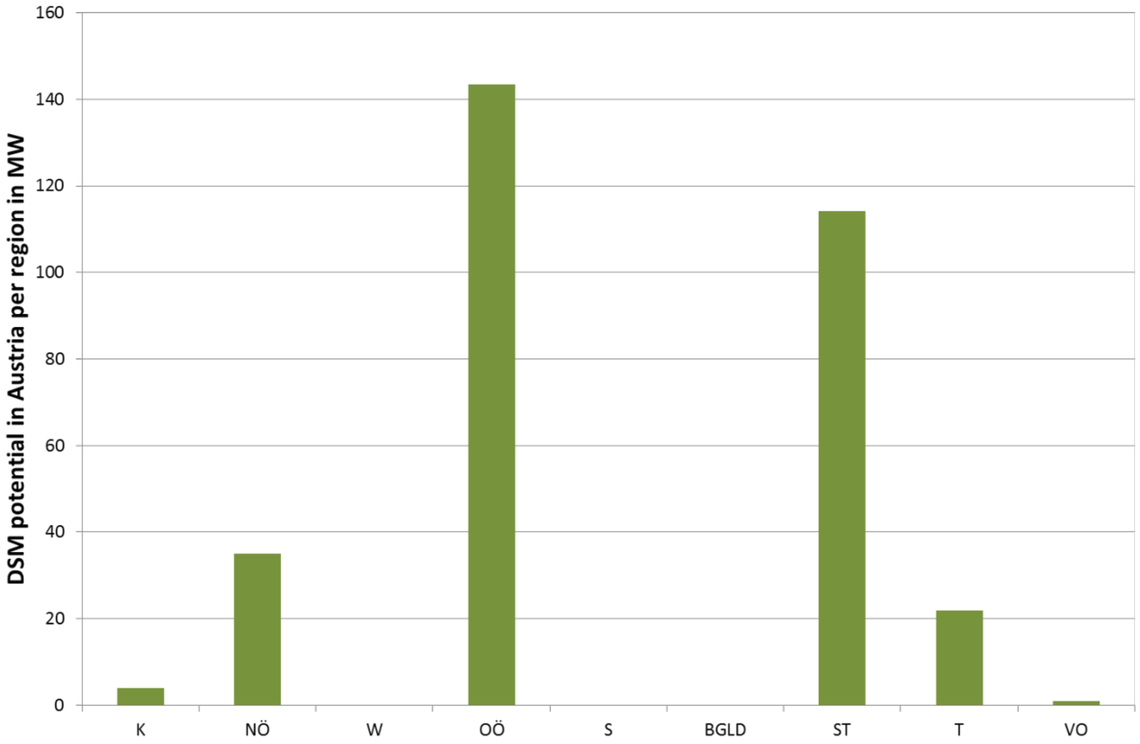


Figure 12: DR potential of different regions in Austria (K…Carinthia, NÖ…Lower Austria, W…Vienna, OÖ…Upper Austria, S…Salzburg, BGLD…Burgenland, ST…Styria, T…Tyrol, VO…Vorarlberg)

Figure 12 shows the DR potential of all regions in Austria. Upper Austria and Styria hold the highest potential of DR measures in Austria by far. Thus, the distribution shown in Figure 12 needs to be taken into account. Assuming that areas showing a high concentration of industry come along with a higher population density, a combination of the DR potential distribution and population density was chosen to be a sufficient approximation to assign DR measures to grid nodes. A rising potential of DR measures (as shown in Figure 13) is taken into account by scaling the DR measures of 2006 up to the corresponding year. This is done equally to the scaling of final consumption.

6 Scenarios of EDRC

Within the EDRC project we simulate two different promising applications of DSM with ATLANTIS. Firstly a reduction of peak loads, as described in chapter 6.1. In this case old, inefficient and expansive power plants which operate just a few hundred hours a year should be replaced by DSM-measures. In theory, the price of electricity at the energy market should decrease. An industrial company has the advantage, that if they shift a part of their electricity use to off peak times, they gain the price difference between peak price and off peak price as additional profit. In addition the electricity system becomes safer for all consumers. The second application is the reduction of redispatch. Redispatch is a second best solution in plant usage because of physical constraints in the transmission grid. The different simulations with ATLANTIS in this case should show how many of these inefficiencies can be eliminated by DSM.

The third application is a calculation without ATLANTIS to find out how much additional profit from tertiary control market can be expected. These additional profits are an estimate because of less available data and less predictability of this market.

6.1 Peak load application with ATLANTIS

The most promising application for DSM is to reduce the peak load, where prices at the energy market are rather high. The price depends on the last plant (which also is the most expensive plant in comparison to the other plants used) in use for covering the actual consumption. In extreme peak load times (app. hundred hours a year), prices are far higher compared to the rest of the year. In these hours, old and inefficient plants are used which therefore only run for some hundreds hours a year. This doesn't result from a need for energy, but because there is a lack in capacity. The most important thing for the electricity system is to ensure that demand and generation is as equal as possible at every moment. A reduction in peak load can help to reduce overcapacities and to operate other capacities at a more efficient level. Therefore the first application within the EDRC project is for reducing the peak load. The peak load application shouldn't be seen as a form of saving energy. It's just a time shift of demand. Leading to a reduction of consummation during peak load hours and resulting in an increase in consummation some hours later. In our approach a few hours does mean 2-5 hours later.

6.1.1 Technical parameters of DSM applications for peak load reduction

The interviews yielded the amount and the technical specification of DSM. This seems to be the minimum technical potential, because not all industrial sites could be visited and the feedback given from carried out interviews wasn't always 100% perfect.

Where no interviews were held, we adjusted and scaled corresponding data from our interviews to fit the industrial site's parameters. For example, if a company in cement industry with 1 Mio tons of annual production does have a potential of 10 MW and another one with 500,000 tons does have 5 MW potential a scaling factor of 1 MW potential per 100,000 tons of annual production can be derived. In similar ways we did an approximation for different branches in a more conservative way. Summing up the DSM potential from our interviews and scaling for non-interviewed industrial sites result in an amount of 320 MW for the year 2012. This is similar to the results from the PhD thesis of Mr. Gutschi (Gutschi C. , 2007). For ATLANTIS we adapted our load duration curve of 2006 with a DSM potential of 300 MW and added an annual increase of 1.2 %. This can be seen in Figure 13. From the information gather in our interviews we know, that approximately two thirds (200 MW) can be shifted once a day for each day from Monday to Friday. The other 100 MW can be shifted once a week. Because of a lack of information, you can't predict which day in a week will have the highest peak load. Therefore we spread out these 100 MW evenly on each working day which leads to an increase of potential of 20 MW each day, resulting in a daily potential of 220 MW. These figures apply to 2006 and also have this up scaling factor of 1.2 %.

A second simulation with an optimistic potential has been done. Here we assumed that industry do have far more potential, but does not know it. This potential was assumed with 1,000 MW, which means 840 MW a day in 2006. The load curve adaption in this case was completely different, but all other assumptions where the same.

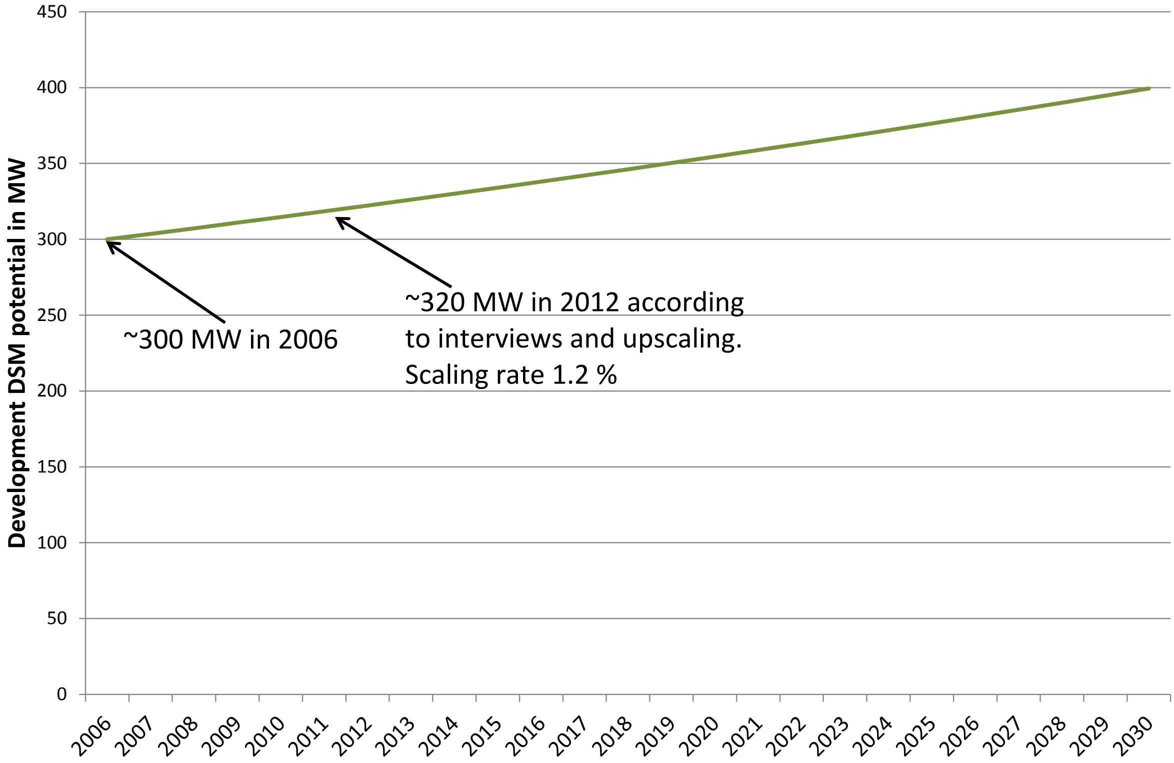


Figure 13: Development of DSM potential in Austria

6.1.2 Input parameters of Simulation

The simulations are based on the consumption data of 2006 from ENTSO-E (ENTSO-E). The consumption data is in chronological order and has to be sorted to a load duration curve. In Figure 14 you can see an example of the unmodified load duration curve of Austria (week 3 in 2006). In Figure 15 you can see the example of a peak load case adaption of the load curve (week 3 in 2006). The example shows week three in year 2006. Because of the static realization of demand, this demand curve and also the DSM potential is just scaled up by factors for the simulation until 2030.

Because of the simulation duration until 2030, it is necessary to give respect to the impact of increasing PV installations in the next years. This calls for an adaptation of the load curve for 2020 until 2030. The changes made in the load curve can be seen in Figure 16. It shows week 26 in 2020.

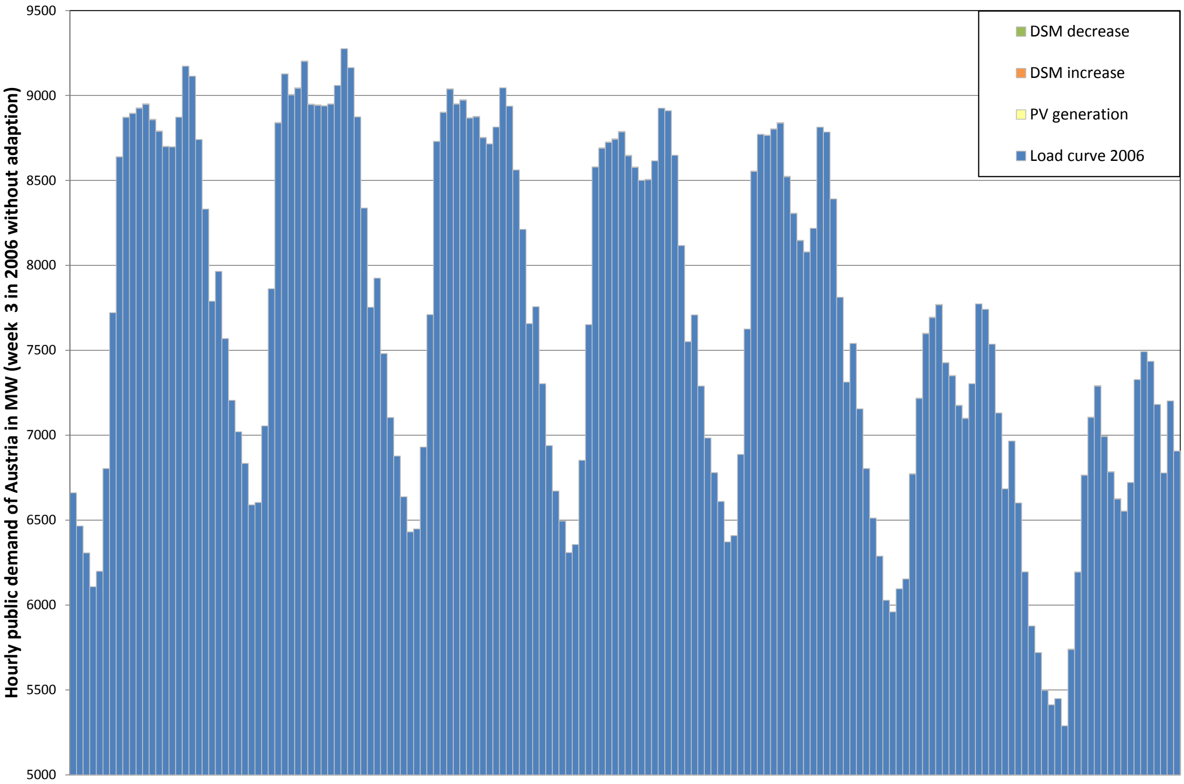


Figure 14: Unmodified load curve of Austria 2006 (ENTSO-E)

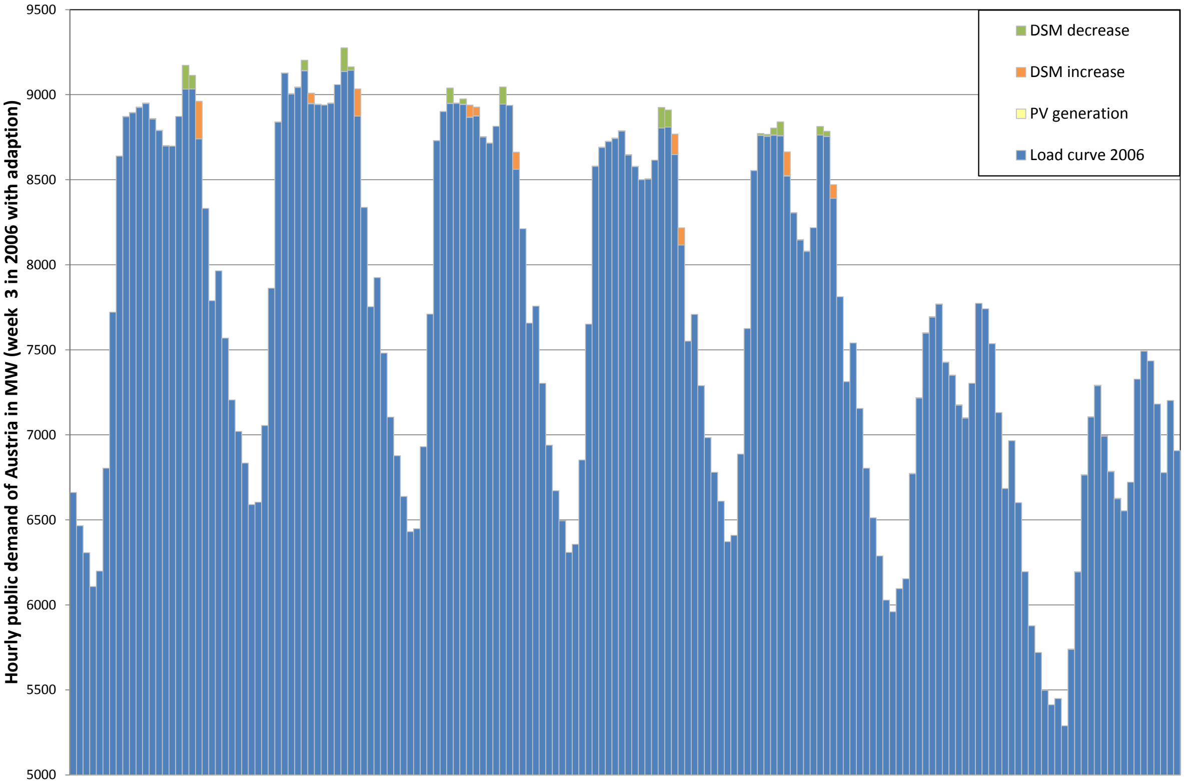


Figure 15: Load curve of Austria 2006 with DSM adaption (week 3 in 2006 – Austria; case 300 MW)

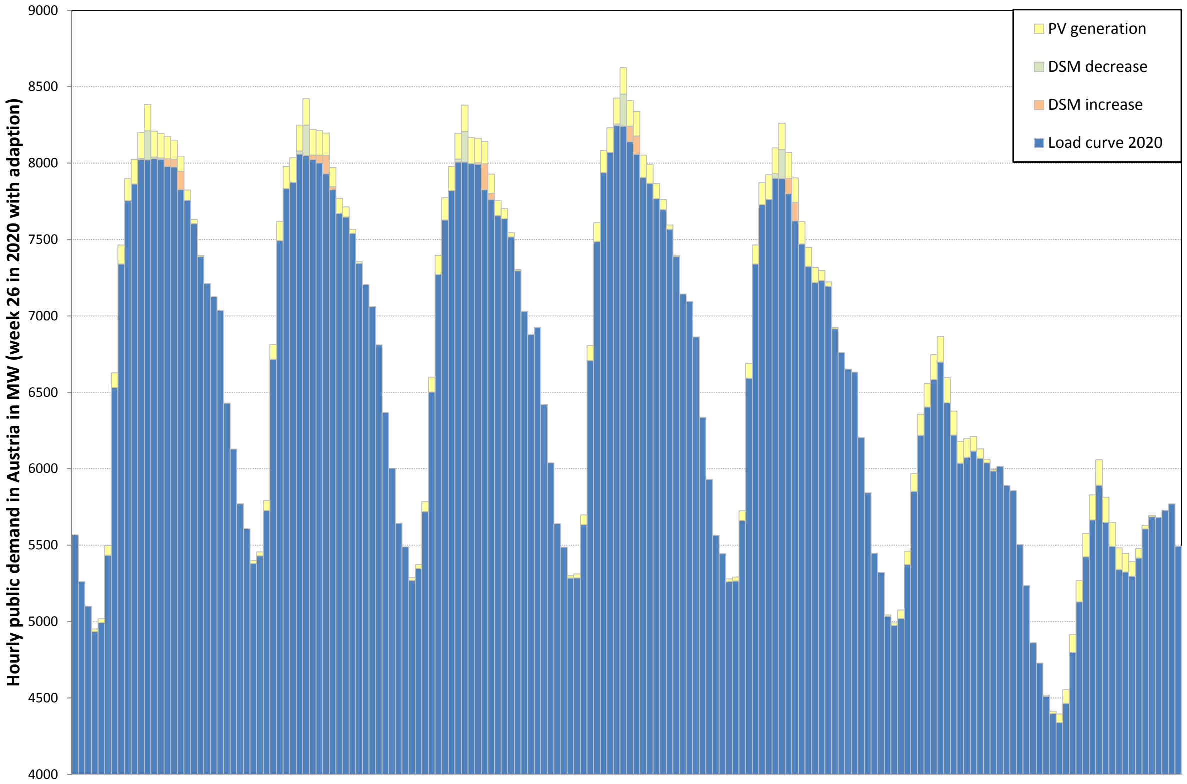


Figure 16: Adapted load curve with respect to PV generation (week 26 in 2020 – Austria; case 300 MW)

A constraint of the peak load application is that the reduced demand has to be used within 2-4 hours after the reduction (300 MW case). This constraint results from our interviews and the fact that not every company is allowed to produce during night time. Even if the night would be optimal to shift the load to, it isn't realistic and therefore not considered in this project.

In the 1,000 MW case the time gap can be up to five hours. To handle this amount of DSM it's necessary to increase the gap, otherwise there would be no real effect because the potential couldn't be used in an efficient way.

6.1.3 Simulation results

There are several effects which are investigated within the simulation model ATLANTIS. These are the impact on the load duration curve, the power generation in Austria, the CO_2 emissions, the changes in production costs and the import-export balance of Austria.

In Table 6 you can find the abbreviations according to the cases simulated for the application of peak load reduction.

Table 6: Abbreviation overview of the cases for the application for peak load reduction

Abbreviation	Description
BASE	Reference scenario used to compare results to “business as usual”
SLS	Adaption of the load curve from the point of view in 2006 (no respect to PV generation); in addition “case 300 MW” or “1.000 MW” is added to clarify the amount of DSM
SLSPV	Adaption of the load curve beginning in 2020 with respect to PV generation); in addition case “300 MW” or “1.000 MW” is added to clarify the amount of DSM

6.1.3.1 Load duration curve

The load duration curve LDC shows the hourly demand of a consumer, region or country, sorted by the demand. In our case, it is the LDC for Austria 2030. As an example you can see from Figure 17 the LDC for 2030 as an outcome of our ATLANTIS simulations. For clarity reasons the Y axis is not set zero. In the lower left corner there is a zoom of the hundred highest demand values of the LDC. As can be seen from zoom, the highest peak load hours can be reduced by approximately 3 %. In the case of 220 MW possible load shift per day. We also did a simulation with a DSM potential of 840 MW per day. But our simulations showed that if the supposed potential is too high there is no more reduction. The breakeven point is about 4-5 % of the peak load in the case of a static optimized load curve for a certain amount of load reductions. If you try to implement more DSM under the given constraints, old peaks disappear and new ones occur which leads to a nearly similar load duration curve as before which means that for a high amount of DSM the time shift duration needs to be increased.

Figure 17: Load duration curve /with adaption for Austria for 2030 (ATLANTIS)

6.1.3.2 Power generation in Austria

An interesting aspect of the application for peak load reduction is the power generation in Austria. In this interpretation we have two different figures (case 300 MW). In Figure 18 you can see the entire generation in Austria except pump-storage. They are not included in the interpretation because of their ability to be a consumer as well as producer. The different levels in Figure 18 represent the different demand situations in the years 2010, 2020 and 2030. The assumptions for the simulation which cause the higher demand for 2020 and 2030 are described in Chapter 0. As a result of the higher demand, the production (or import) has to increase. A slight difference in generation can already be seen in Figure 18. Gas fired plants contribute the most to these differences. The high contribution of gas fired plants calls for a separate consideration, which is shown in Figure 19. Gas-fired power plants often set the price in the electricity systems, due to the fact that they are the last operating plant in the merit order. If there is a load shift, it is likely that a formerly needed plant isn't used anymore. This could also lead to lower generating costs, which is described in 6.1.3.4.

A possible case is that imported electricity is cheaper than generation in Austria and if there are enough net capacities, this could also be a reason for turning down the generation in Austria. The analysis of import and export can be read in chapter 6.1.3.5. The figures for the case 1,000 MW are located in the annex.

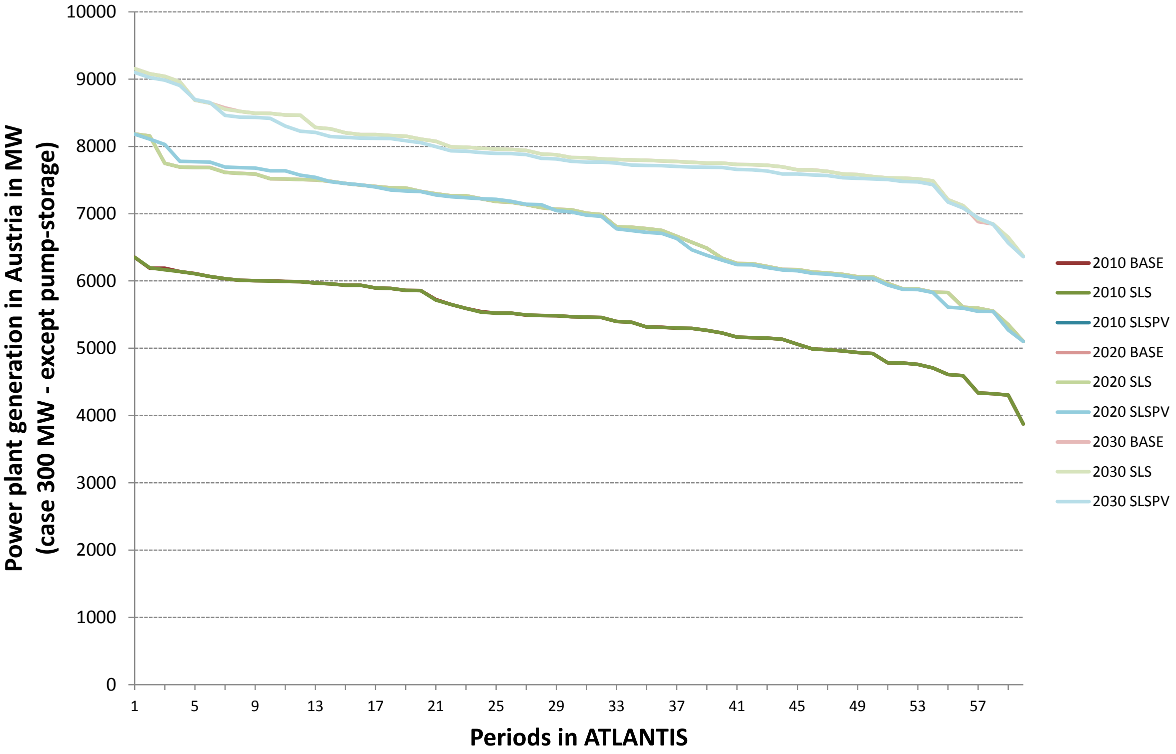


Figure 18: Overview of generating in Austria in case 300 MW (except pump-storage)

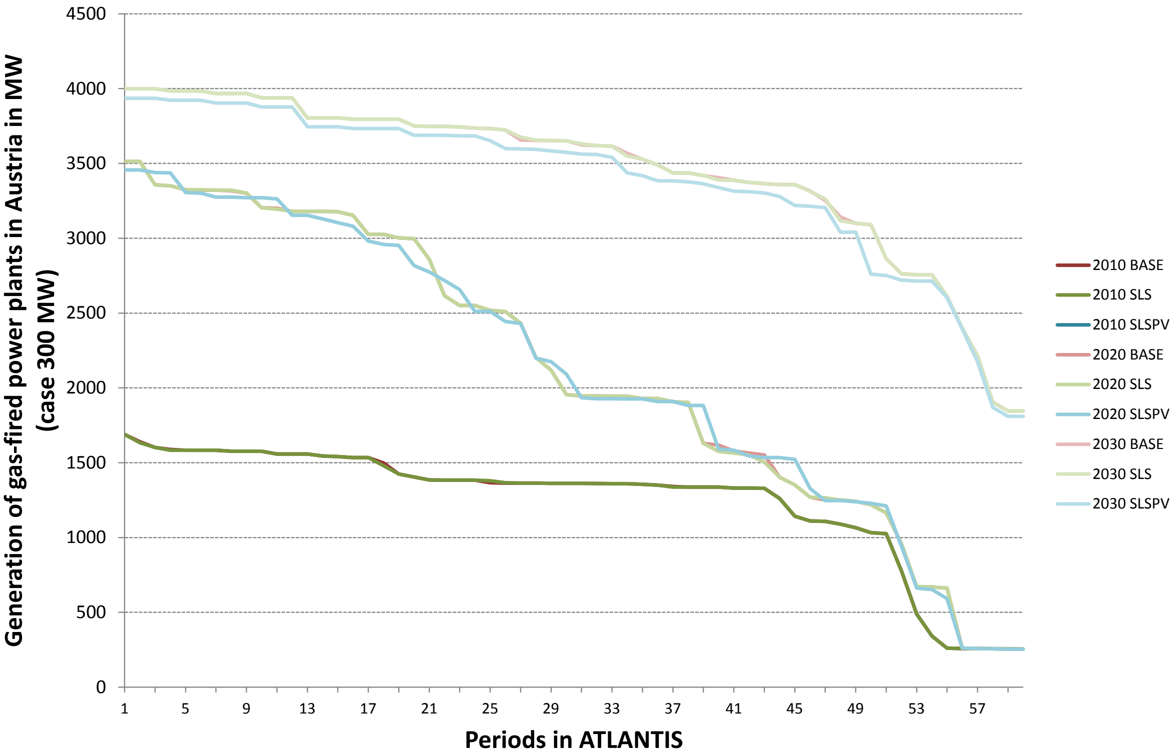


Figure 19: Generation of gas-fired power plants in Austria (case 300 MW)

6.1.3.3 CO_2 emissions

Figure 20 shows the CO_2 emissions of different thermal technologies in Austria. Because of the small differences in generation also the CO_2 emissions do not vary much. In case of SLS 300 MW the CO_2 emissions nearly remain the same as in BASE. In case of SLSPV 300 MW there can be seen a reduction between 1 and nearly 3 % of CO_2 emissions. This reduction comes from shifting peak load in off-peak hours. In off-peak times the plant mix in Austria is lower than in peak hours. The simple shift without respect to the installed PV and its generation in the next 20 years does not lead to high significant findings. But if attention to the PV generation is paid, there can be seen the supposed reduction of CO_2 emissions.

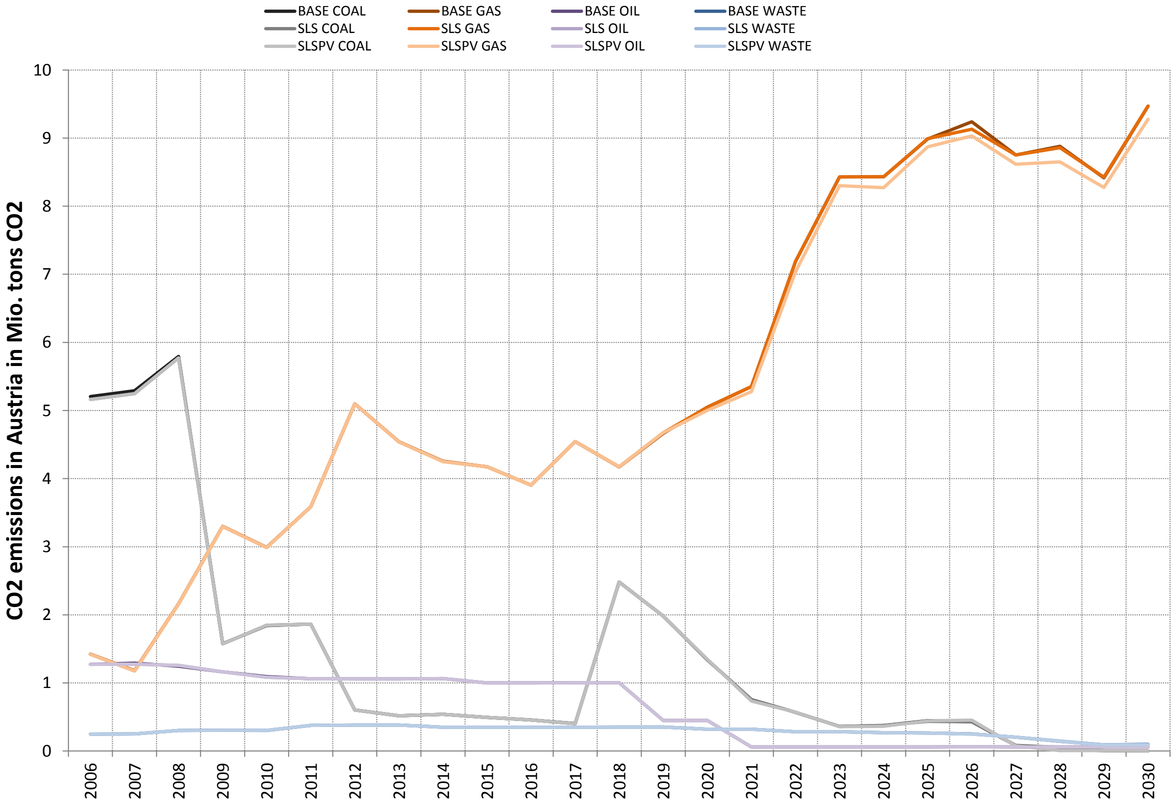


Figure 20: CO_2 emissions of thermal power plants

6.1.3.4 Changes in production costs

The changes in production costs can be seen in Figure 21. The case with an adapted load curve for PV-optimization was simulated from 2020 to 2030. As can be seen, the PV adaption leads to far better results compared to the case without the adaption. The main difference is the reduction of the peak from about 11 am to 2 pm through the PV generation. As a result more DSM is left to cut the peak in the evening, which leads to lower generation costs. The Figure includes the generation costs itself as well as the differences from import and export. This is the result of the simulation model ATLANTIS and represents a possible solution under given constraint (see Chapter 5). The lower generation costs derive from a more effective electricity system, because there is less need for old, ineffective and cost intensive generation capacities. The lower generation costs could be a benefit for the producers and for the consumers as well and may lead to lower electricity costs for all consumers. Also costs for import of energy are included in this examination. The only case where the electricity system gets more expansive is the case 300 MW potential in 2025 because of high import rates. The 300 MW case with PV adaption does show a reduction of costs like all other cases in this year do.

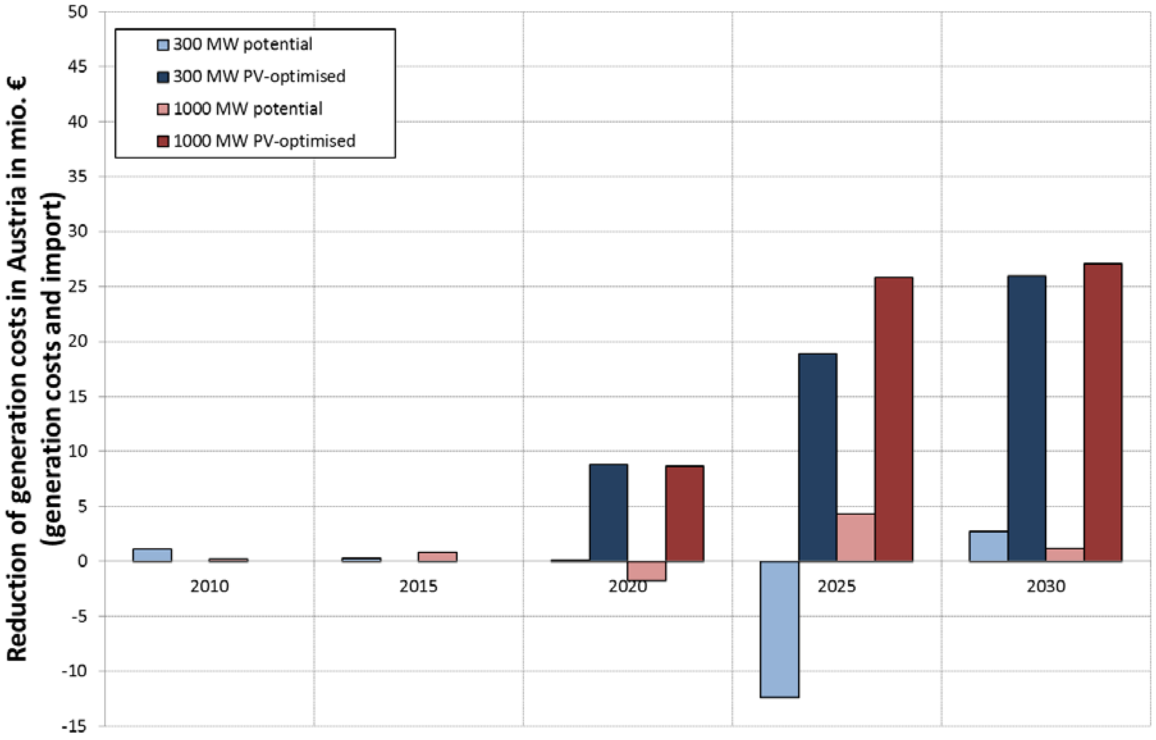


Figure 21: Reduction of production costs in Austria

6.1.3.5 Import-export balance

Every adaption in demand leads to a variation in generation or in import/export balance. This can be caused by different prices on the energy market or by different net situations which can enable more or less import/export. In Figure 22 the import/export of Austria from 2010 to 2030 can be seen. This is an outcome of ATLANTIS with the preconditions of the simulation and without any DSM measures.

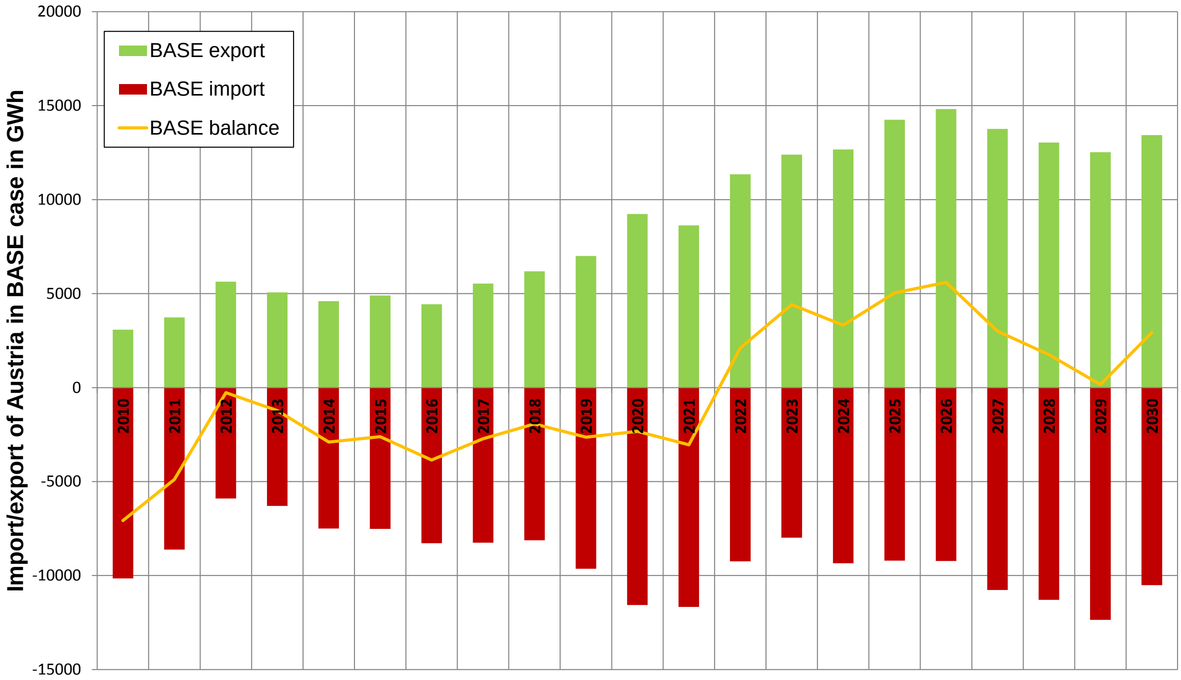


Figure 22: Energy import/export simulated in ATLANTIS for the BASE case

In comparison to Figure 22, in Figure 23 the changings to the BASE case can be seen. Because of simplicity only the changings in balance between import and export is shown. As can be seen is the SLS 300 MW case nearly the same as BASE. In case SLSPV 300 MW a trend to less export (more import) can be seen. This is because of the shift of demand from peak hours to off-peak hours. In these hours energy often gets imported because of lower generation costs in countries around Austria. But on balance Austria remains an exporter from 2022 to 2030 same as in BASE case (except SLSPV 300 MW in 2029).

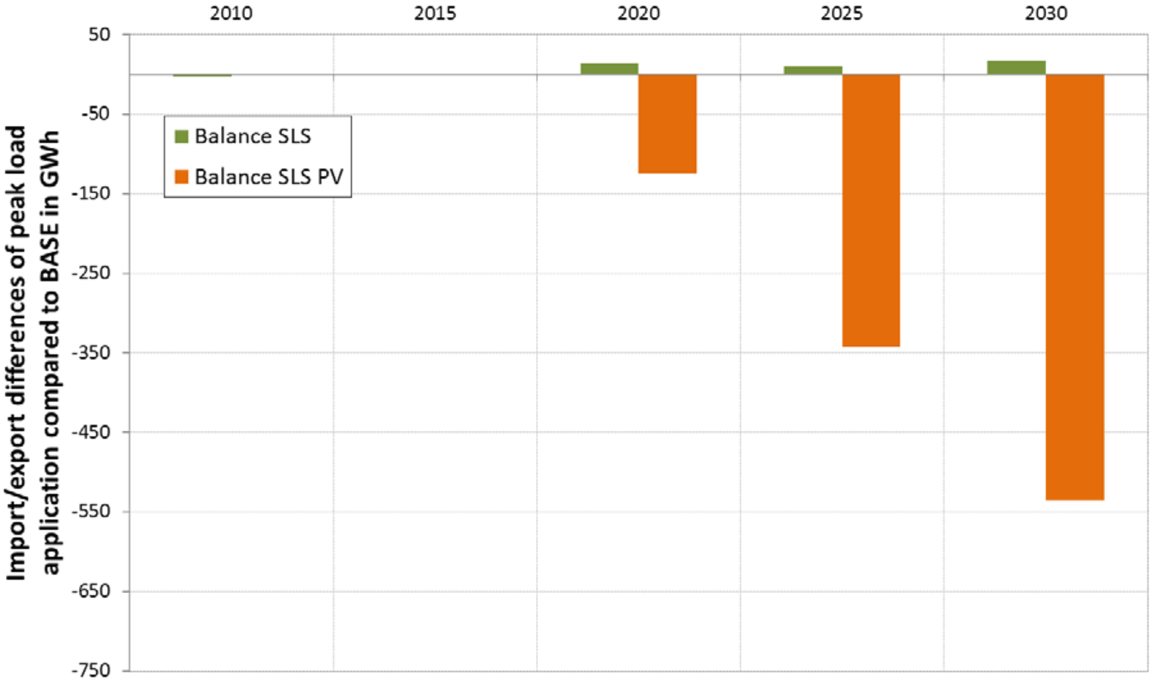


Figure 23: Changings in import export compared to BASE case for SLS 300 MW and SLSPV 300 MW

6.2 Showcase: Possible redispatch reduction as an EDRC application

Another promising application for DSM is to reduce the need for redispatch. The term redispatch describes the alteration of a cost optimal dispatch of power plants according to the market as a result of physical constraints. The grid, especially the transmission grid, is not able to transfer the generation to the places where high load occurs. As a result the congestion of a transmission line can cause a change in the power plant schedule. If the plant generates less than it should from an economic point of view, it is called negative redispatch. Otherwise, if generation from an expensive plant has to be increased, it’s called positive redispatch. Because of the low variable generation costs and the high degree of eco-friendliness, renewable energy sources shouldn’t be the victim of (negative-) redispatched at all. The main aim is to discharge the transmission grid that RES don’t have any constraints for their generation. The second aim is to reduce the costs for redispatch.

6.2.1 Technical parameters of DSM application for redispatch reduction

For redispatch reduction, we assumed to have just one concentrated potential for DSM at one node. Now we can identify the different impacts of DSM on different nodes. One requirement being, that the selected node does indeed prove capable of providing any DSM at all. A further constraint for node selection from our side was that the generation structure at that nodes are predominantly renewable. In the end we took five nodes located in Lower Austria. Their locations vary from Lower Austria's border to Burgenland, Styria to Upper Austria.

6.2.2 Input parameters for the simulation

The first step was to analyse the generation structure of the different nodes in Austria. The main criteria's to choose a node were DSM potential and RES generation. Our investigation lead us to five different nodes, all of them located in Lower Austria. As an example the parameters for the node Ternitz 220 kV is shown in Figure 24.

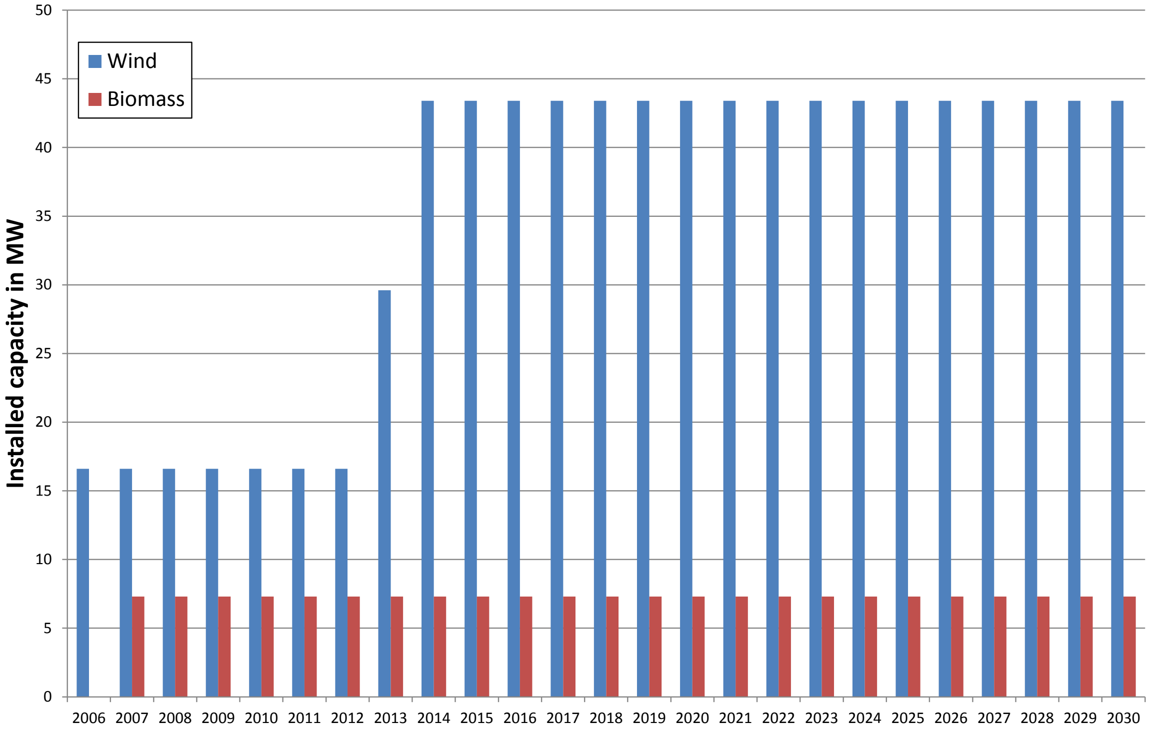


Figure 24: Installed capacity at example node Ternitz (220 kV)

The nodes resulting from this first analysis were Bisamberg (220 kV), Sarasdorf/Stixneusiedl (400 kV), Ternitz (220 kV), Ybbsfeld (220 kV) and Wallsee (220 kV). The corresponding graphs of the installed capacity at those nodes can be found in the annex.

Two different cases for the application "possible redispatch reduction" were simulated:

The first one considers a DSM potential of 40 MW at one node. In order to meet the parameters of the 40 MW case, the load curve with a DSM potential of 300 MW needs to be scaled down to 40 MW. The procedure is the same for all other simulations with a DSM potential other than 300 MW. The simulation is an iterative process where one node after the other receives a DSM potential of 40 MW. After that, the results of the different simulations get compared to the base simulation which is without any DSM influence. This represents a rather conservative point of view regarding the DSM potential.

For the second simulated "possible redispatch reduction" case a potential of 200 MW was considered. The procedure was the same as above. For this case, the load curve with 1,000 MW gets downscaled to fit the 200 MW potential. This is the optimistic case for possible redispatch reduction.

6.2.3 Simulation results

There are several effects which are investigated within the simulation model ATLANTIS. These are the impact on the redispatch variation by using DSM at different nodes, CO_2 emissions and the different usage of plant types in Austria.

6.2.3.1 Redispatch variation by using DSM at different nodes

In the first step the changes in negative redispatch at the example nodes have been investigated. As Figure 25 shows, the generation structure at these nodes has no influence on the variation of redispatch. This means that DR can influence the need for redispatch independent from the place of occurrence. Because of less redispatch of renewable energy sources, there is no significant improvement by DR. The highest variation by means of redispatch can be observed on gas fired power plants. Compared to RES these units cause higher costs of redispatch for the electricity system. Therefore the redispatch of these units will be reduced first. In the year 2015 in Figure 25 there is an increase of negative redispatch. This positive change in negative redispatch happens just in 2015 because of changes in the plant mix. In the following years a reduction of negative redispatch is the same like in the years before.

But there is not necessarily a decrease in negative redispatch because of DR. In the case of 200 MW DR potential concentrated at one node the simulation leads to an increase in negative redispatch which can be seen in the annex. This increase occurs because of the high value of shifted DR at one node which means that not every amount of DR can be handled at one node (split makes more sense).

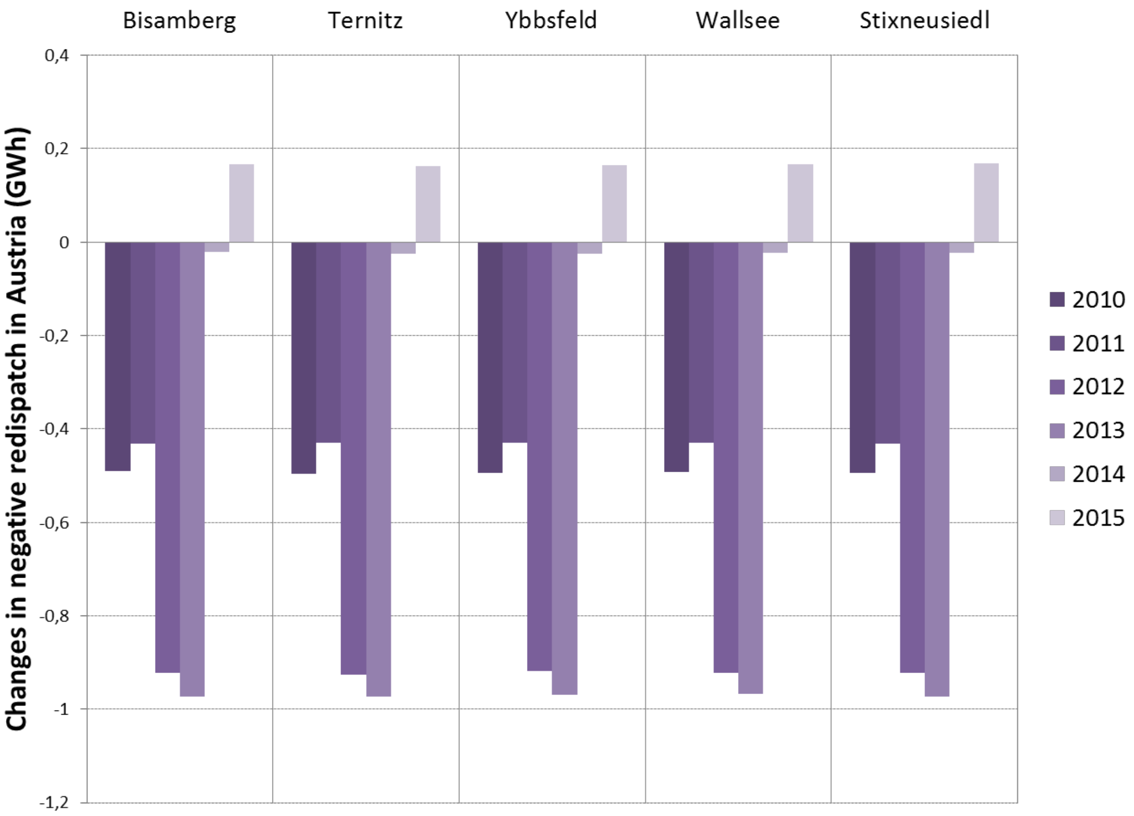


Figure 25: Changes in negative redispatch at different showcase nodes in Austria between 2010 and 2015

6.2.3.2 CO_2 emissions

Also in the case of possible redispatch reduction a reduction of CO_2 emissions can be seen. The absolute emissions for the generation of electricity in Austria are about 6-7 million tons of CO_2. The variation of reduction in different years is a result of different grid situations and generation structures. Possible impacts can be if new plants are built in this time or old plants stop operating. Also price variations at the energy market or a different generation structure in neighbour countries can vary the energy mix and thus the CO_2 emissions. Also the changings in redispatch from emission intensive technologies to “greener” energy sources is a part of this reduction. A reduction of CO_2 emissions can be seen every year until 2030.

Figure 26: CO_2 emissions at the showcase test nodes

6.2.3.3 Different usage of plant types in case of DSM

At all a lower use of power plants occurred in the showcase. This is the result of shifting load from peak hours, where Austria produces energy competitive to its neighbouring countries, to off-peak hours where our neighbouring countries do have a cheaper energy mix in the observed time frame from 2010 to 2015. Because of international trade and available grid capacity import is cheaper in certain hours where a raise of load occurs because of DR. The range of reduction in Austrian generation is about 100 to 200 GWh per year, which means less than 0.3 % of annual production. The main part of this reduction is given by gas-fired power plants which are usually the last traded units in the electricity system. Figure 27 shows the reduction of generation of all power plants in Austria. About 90 % of this reduction is seen by the operation of gas-fired power plants. In our case, by looking at these five nodes, the reduction of generation seems to be independent from researched nodes just like the redispatch variation.

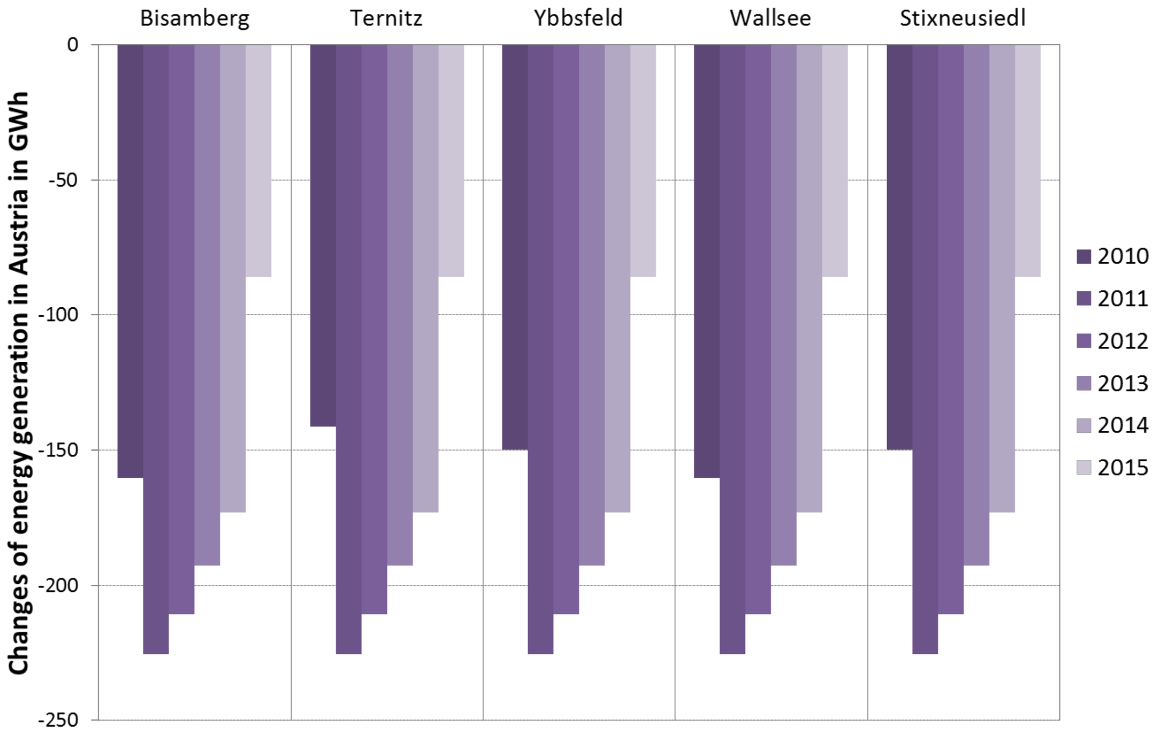


Figure 27: Changes in generation in Austria (all plant types) in GWh

6.3 Application of DSM for the control energy market

The third promising application for large scale DSM in industry is the control energy market. Since 2012 the APG is responsible for the primary-, secondary and tertiary control energy market in Austria. As a partner of EDRC project, the details concerning the market can be taken from APGs final report.

6.3.1 Technical parameters of DSM applications for control energy market

Because of the short response time and the automatic call up, DSM is not suitable for the primary and secondary control market. An external interrupt (f.i. from a TSO) is not acceptable for an industrial company. Such an interrupt can cause massive damage on the production machines or in a worst case scenario even on human beings (depending on the contact of humans with production machines).

As a result a DSM application only makes sense for the tertiary control energy market (Market Maker MM), which is the only control energy market considered in the EDRC project. The call for tertiary control energy comes manually by the TSO. In the case of EDRC it is possible that not the company itself gets contacted, but the aggregator which coordinates a certain number of companies. He then calls the corresponding companies which will then change their actual consumption.

The first idea for this application was that industrial sites can either reduce or raise their consumption of energy/capacity. Outcome result of the interviews was that a raise of the consumption can't be achieved as easily as someone might think. Normally such companies operate near their physical maximum of consumption, which renders an additional demand increase difficult.

As a result, only a reduction of production is a possible solution (e.g. gas turbines) for DSM in this analysis. That's why we analyse positive (reduction of consumption) and negative (rise of consumption) redispatch with DSM statistically, but possible earnings are calculated only for the positive case.

The tertiary control energy market with its prequalification terms is described by the APG as the specialist for this market in Austria.

6.3.2 Preparing data for the calculation

In the following analysis of the control energy market only the type "Market Maker" is considered, which is described in detail by the final report of APG. For the calculation of possible gains from DSM use on the control energy market, two components are important. The first one is the power price. The company will get this money independently from whether they had to contribute or not. All bids which get collected at a certain time/date get sorted by the bid price from low to high. The bids (in MW) get added until a certain amount of positive and negative tertiary control energy is reached. The last bid can be split or APG accepts more than the minimum amount for a product (pos. /neg.). All bids made without sales tax in €/MWh.

The second one is the energy price. The accepted tenderer of power price auction have to bid for the energy price. Possibly the most expensive accepted tenderer in the power price auction could offer for the lowest energy price. The energy price bids get sorted into the daily merit order and called from lowest to highest energy price. A tenderer can correct the energy price bid all the time if this leads to lower costs for the electricity system.

As already mentioned since 2012 the APG is responsible for the entire Austrian control energy market. Until 2012 this was, to a certain part, the duty of the APCS. Therefore only limited data for our calculations could be obtained. We do have the results of the power price auction and the energy prices for calls from the APG for 2012. Unfortunately we have less data from the years before 2012. The energy price data with calls (time/date/duration/price) and an average of power prices can be downloaded from APCS homepage (APCS, 2012). So the time series for the calculation of possible earnings at control energy market is very short which needs to be considered when it comes to the reliability of the results.

6.3.3 Bid structure at tertiary control energy market (Market Maker)

As an outcome of the interviews and further investigations only the positive tertiary control energy market seems to prequalify for a use of DSM. In a similar way to the peak load application and the reduction of redispatch, only a time shift of demand can be achieved by this application. There is no sort of energy saving. As already mentioned, the earnings for capacity are independent of being called to deliver or use energy.

6.3.3.1 Capacity price

In the main part of this report only the positive tertiary control market gets described in detail – which is called "Ausfallsreserveleistung ARL" in Austria. From Figure 28 you can see the development of the positive capacity prices from January to September 2012. Unfortunately that's the entire time series available for the statistical evaluation of the capacity price. Therefore the results are just an estimation of possible earnings. As you can see in Figure 28 there is a peak in March and/or April which couldn't be investigated in detail because of non-existent data.

ARL is defined as supply to the control area of APG. This supply can be provided by power plants or by consumers. Power plants which do not operate at 100 % of their possible generation (at least for the time slot of the bid) can increase their output for to fulfil the contract for ARL. Consumers and especially industrial consumers often have two options to provide positive tertiary control energy. Mostly the reduction of their demand is the preferred solution. A second possibility is to increase the customer generation if possible.

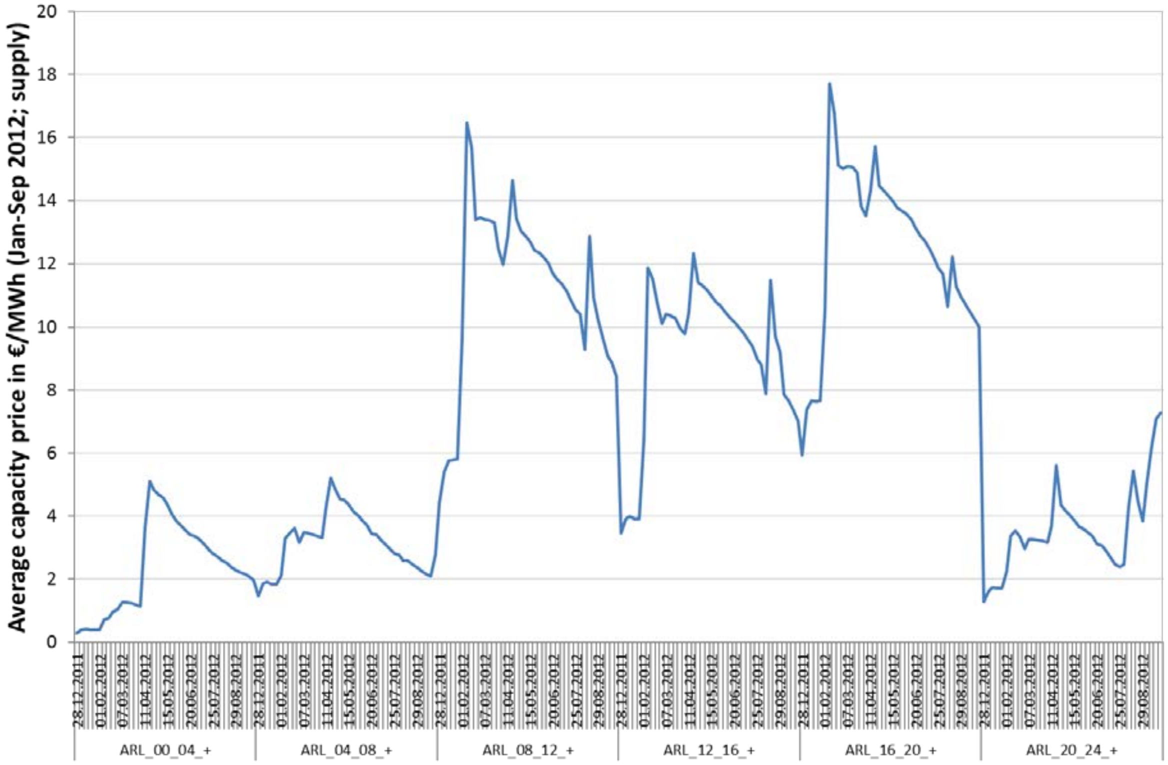


Figure 28: Average capacity price for the supply of energy/capacity (positive)

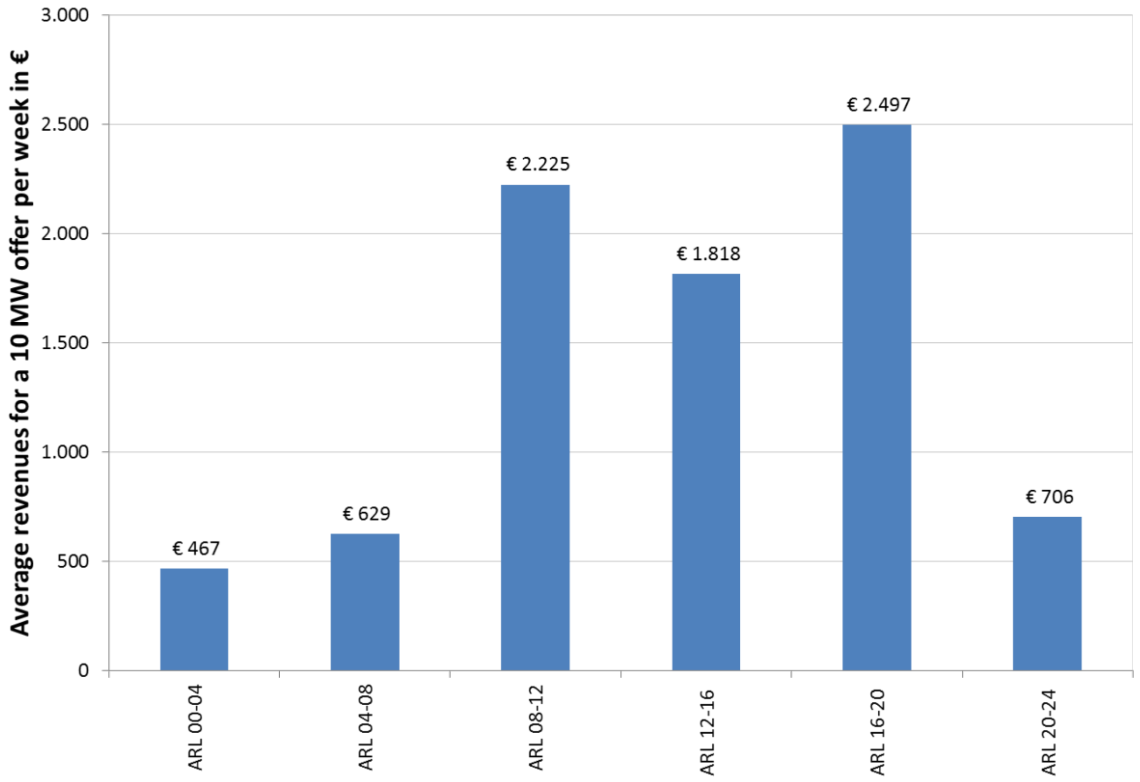


Figure 29: Average revenues for the minimum bid of 10 MW at positive tertiary control market (Mon-Fri)

Figure 29 shows the average earnings for providing capacity at the positive tertiary control energy market (ARL) for the Market Maker auction from Monday till Friday. The time slots for the single bids always have duration of four hours. For example a bid from 4 to 8 am means that from Monday till Friday the bidden capacity has to be available for a call at the given time. If the capacity is not available, the bidder can be punished. As can be seen in Figure 28 there is a big time variation in possible earnings. The further calculations will be done with the average revenues from Figure 29.

6.3.3.2 Energy price

The second part of a Market Maker bid is the energy price. There is no connection between capacity and energy price. A low capacity price does not imply that the bidder gets called. After being accepted in the capacity auction, every successful bidder has to give up a bid with his energy price. Until the delivery time and date he can change his bid but only if it's an advantage for the system. If you have to actually provide tertiary control capacity doesn't depend on your capacity price, in this regard only the energy price matters. The bids get sorted from lowest to highest in case of supplying energy and from highest to lowest in case of using additional energy. Depending on the need for control energy the bids get called in this order.

The database for this analysis is better than the one we had for evaluating the capacity price. The data are from APG for 2012 Jan-Oct (APG, 2012) and from APCS (APCS, 2012) for 2011. This amount of data is not enough for a statistical significant analysis, but enough to get an overview over possible earnings.

In Figure 30 you can see the count of positive and negative tertiary control energy calls in 2011. In Figure 31 you can see the same for 2012.

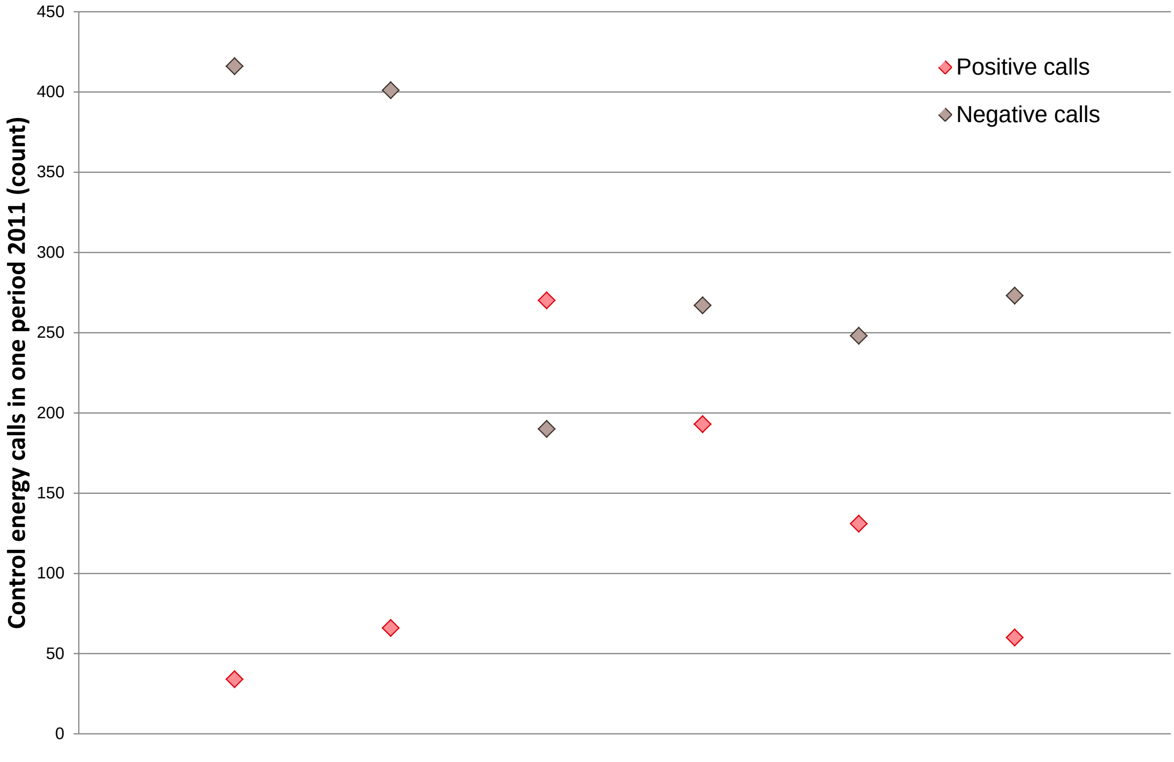


Figure 30: Count of positive and negative tertiary control energy calls 2011 (APCS, 2012)

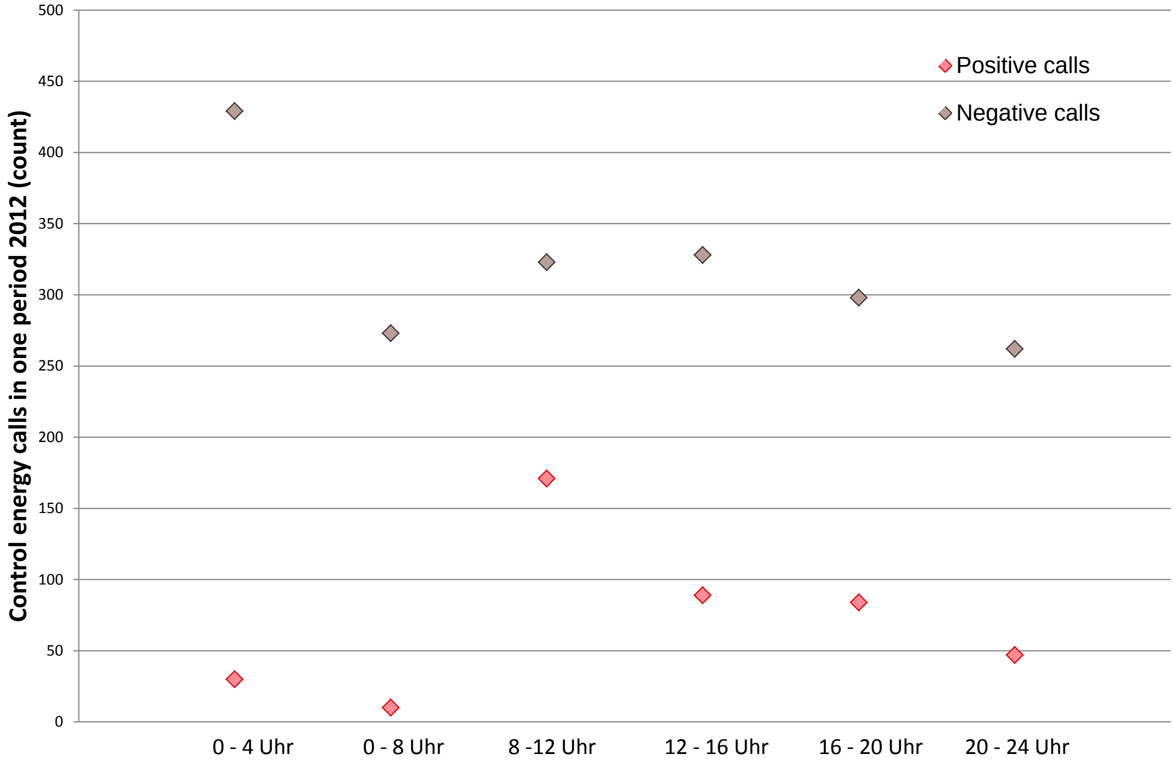


Figure 31: Count of positive and negative tertiary control energy calls 2012 (APG, 2012)

As can be seen negative calls occur far more often than positive calls. Figure 32 and Figure 33 show the price variation of the positive calls (ARL) in 2011 and 2012. For the negative calls (TRL) these price variation are shown in the annex.

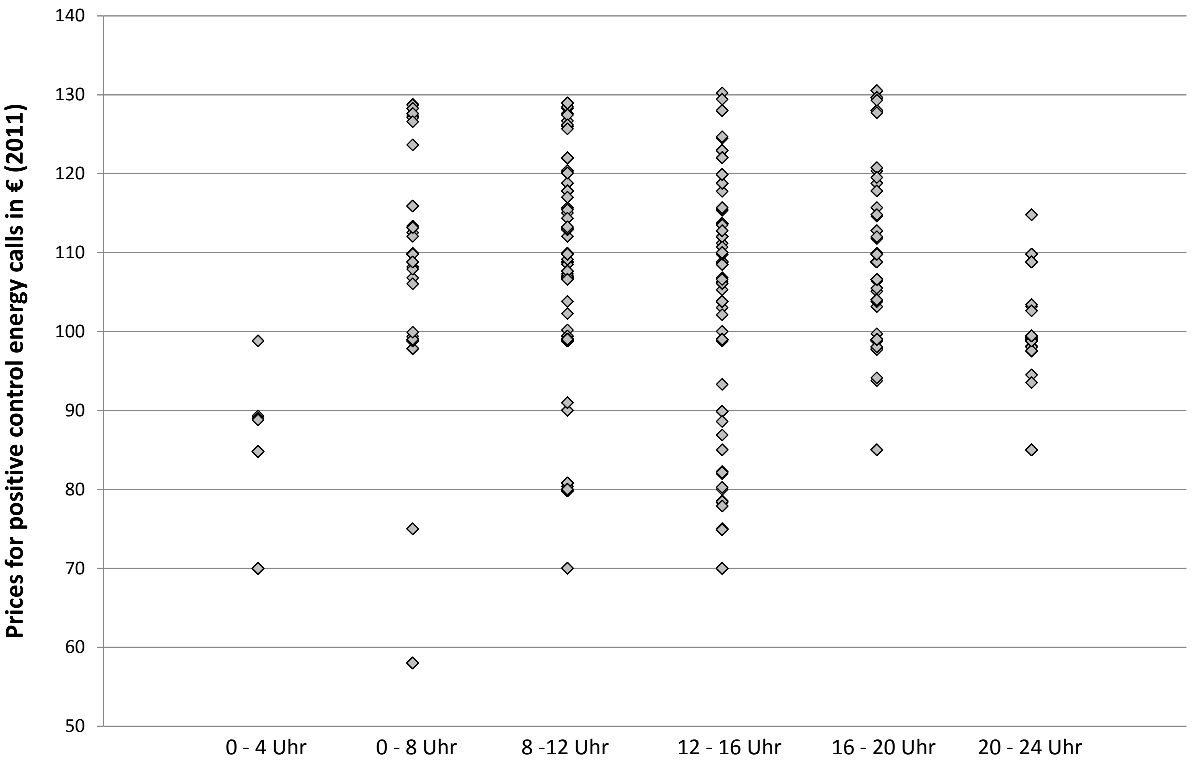


Figure 32: Price variation of positive calls 2011 (APCS, 2012)

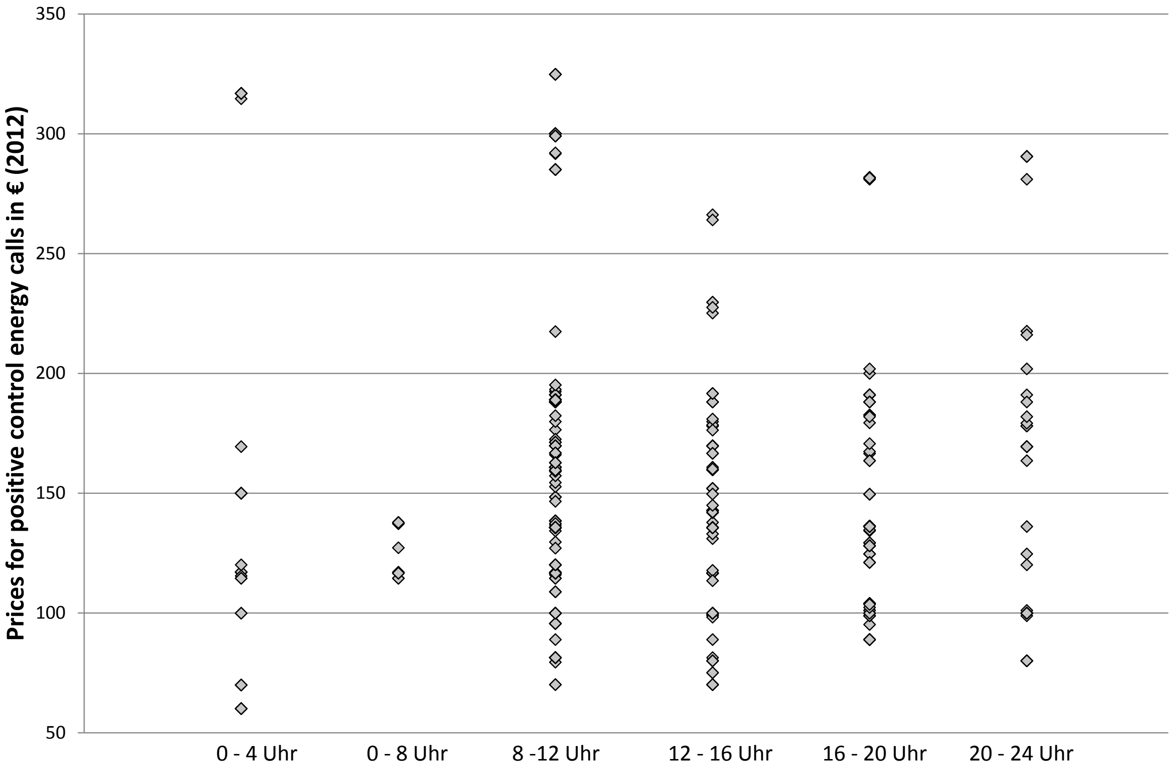


Figure 33: Price variation of positive calls 2012 (APG, 2012)

As can be seen from these figures, the prices in 2012 were by far higher than in 2011. The beginning of the Y axis in Figure 32 and Figure 33 is set up to 50 €, because there were no calls below 50 € for positive calls in the last two years. You will find a calculation of possible incomes in the conclusion.

6.3.4 Possible incomes at control energy market

In the previous chapter the capacity price and the energy price which are possible incomes at the Market Maker market get described. Because of the short time base of available values possible incomes cannot be calculated. It can be seen in Figure 29 which average prices for capacity where achieved in 2012. Out of this data possible average incomes can be derived. The incomes at the energy market depend on the actual situation at the spot market and cannot be calculated in a significant way due to the possibility that no control energy is needed in the call-period. Because of the decoupling of energy and capacity price a bidder who has bid a high capacity price can have a low energy price and therefore be called very often, or vice versa. Another effect which makes this calculation difficult is that every new bidder at the market influences the clearing price. If DR has high capacity costs, there will be no influence on the market. If DR measures are competitive to existing bids, the capacity price will be lower in future than today. There will be further investigations needed to find out the costs for cancelling production in special companies. This figure will be the minimum value for bidding at control energy market. Hence at this point there is no further calculation of possible incomes, but an interested person can calculate his possible incomes because of the data from the previous chapter.

7 Conclusion

There is definitely high potential in Austrian industry for DR. This is one of the results of the interviews and the up scaling of DR potential in Austria. The up scaling is based on the fact that most of the different industrial sites of one branch do have similar potentials. A high DR rate can help to keep the electricity system safe and cheap for the future. DR can support power plants especially in times of peak load. But because of less knowledge and experience with DR, companies often have concerns or do not see the potential. They fear interrupts in the process chain and therefore companies often are not open minded for DR measures. That’s why the most promising way to implement DR in large scale will be to talk to people and analyse their demand and process chain. After that is has to be decided which application in which dimension of power can be done at an industrial site. The pivotal question will be how fast different business models for different branches or processes will be developed to assure companies to do DR. Another restriction is if a company has a good order situation there is rather little incentive to risk production output because of load management, even if it would be possible.

The simulations in the report for the application peak load reduction are based on the assumption that in 2012 320 MW DR is available (interviews, up scaling). For the application of redispatch reduction just 40 MW are assumed in the main part of the report, but this 40 MW are concentrated at one node. As can be seen from our results out of ATLANTIS, a decrease of costs for the supply of all customers occurs as well as ecological benefits because of reduction of CO2 emissions in most of the simulations. Also one effect is that the use of old plants for peak load hours can be limited. But DR response does not replace new plants; it is a measure to operate existing plants in a more efficient way.

In case of tertiary control energy market (Market Maker) the data were not satisfactory for a statistical analysis. The possible earnings are fluctuating a lot over a year. Even if there definitely is a potential for this application further investigations will be needed. But there are processes in industry which fulfil the prequalification conditions and do fit for this application.

There are also other stakeholders which could have an interest in DR in industry. These are for example transmission system operators (TSO) and distribution system operators (DSO). They may have a support out of DR in critical grid situations, are able to influence the load flow over the national borders or they can reduce their peak load demand (DSO pays for the maximum load a fee to the TSO).

The findings of the EDRC project could be an input for dissertations at the Institute of Electricity Economics and Energy Innovation. The dissertation topics are capacity markets and capital stock in the electricity system. Therefore DR has an impact on these topics and this work can be used as a base. Parts of this work were published at the "8. Internationale Energiewirtschaftstagung" in Vienna in February 2013 (Hütter, Schüppel, & Stigler, 2013).

The results of the ATLANTIS simulations in the main part of this report are only valid under the given input parameters. The most important input parameters are derived from the 450 ppm scenario of World Energy Outlook 2010 (International Energy Agency, 2010) (e.g. fuel prices), the National Renewable Energy Action Plans in case of development of generation of renewable energy sources in Europe and the Ten Year Net Development Plan for the transmission grid. The main findings in regard to the use of DR measures are:

- A cost benefit for the whole electricity system
- Lower CO_2 emissions in comparison to a system operating without DR
- Power plants can be operated in a more efficient way
- The European context of DR should be considered in further investigations

Another result is that possible effects do not increase linear with an increased DR potential. The results with an about three higher DR potential as in the main part (results are in the annex), do not show greater effects for the electricity system. The main advantage of such a high potential could be a higher availability of DR potential when it is needed.

8 Next steps

Further steps of this project should be to set the focus from Austria to the entire European region. The interdependencies between countries all across Europe were just a small part of the EDRC project. Therefore a detailed analysis with DSM in all countries with respect to their individual industries and especially to their demand variation during the day, week and year are important.

A further research of possible applications and stakeholders (interviews) should be done as well. More interviews with different stakeholders and with operators of industrial sites are necessary. The image of DSM measures should be changed and brought to relevant companies. Often companies do have a misimpression of what DSM is, what its advantages could be and how to set it up in their special production process.

A more practical approach would be a large scale prototype or commercial use of a system that aggregates many DSM-suppliers to one pool. Such systems could help to support the grid as well as to operate the existing power plants in a more efficient way. The benefits of a large scale system may lead to less need for new power plants, a more ecological way of generating electrical energy and to a safer system for all users.

9 Annex

9.1 Additional information to application peak load reduction

9.1.1 Load curve adaptions in the case 1,000 MW

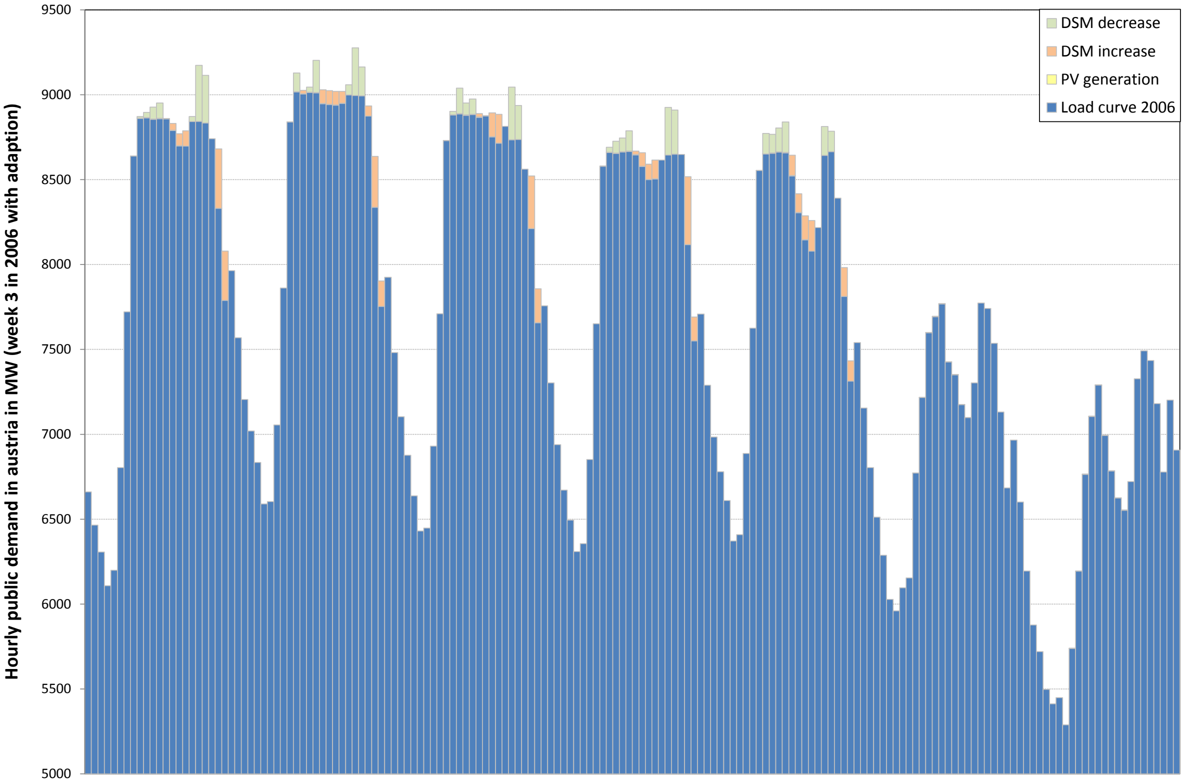


Figure 34: Load curve of Austria 2006 with DSM adaption (week 3 in 2006 – Austria; case 1,000 MW)

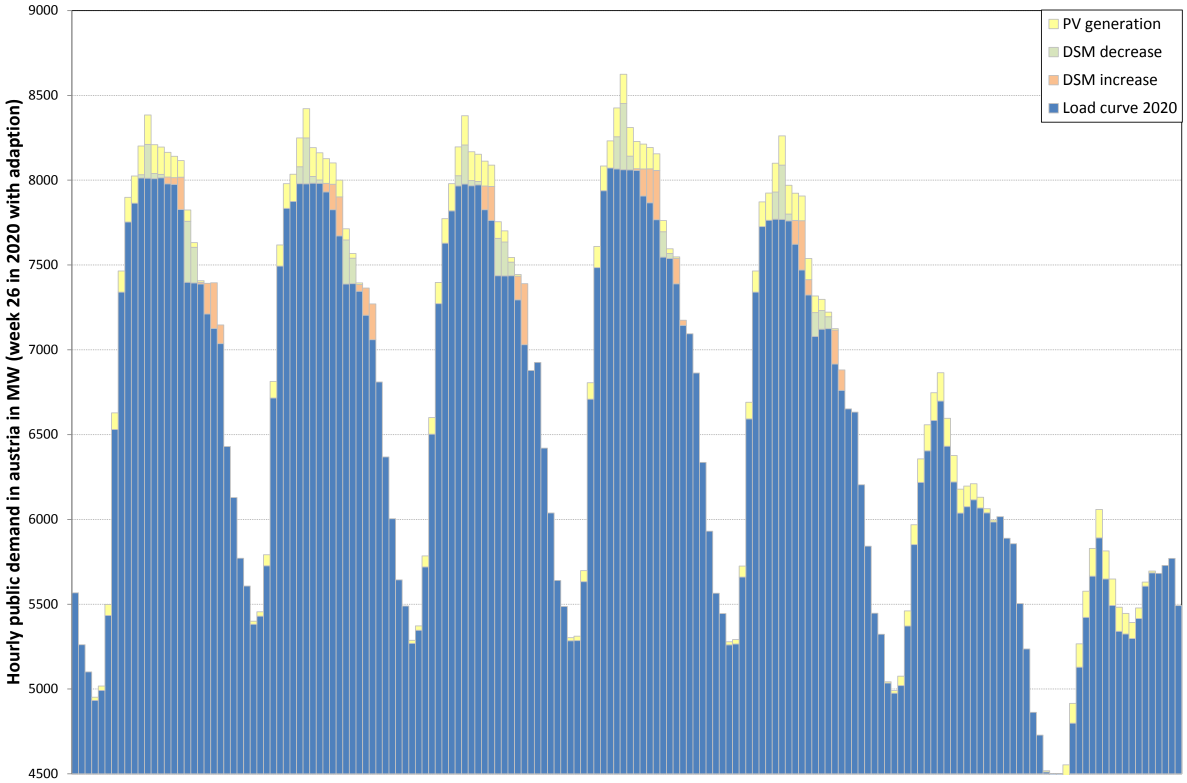


Figure 35: Adapted load curve with respect to PV generation (week 26 in 2020 – Austria; case 1,000 MW)

9.1.2 Generation in Austria in case 1,000 MW

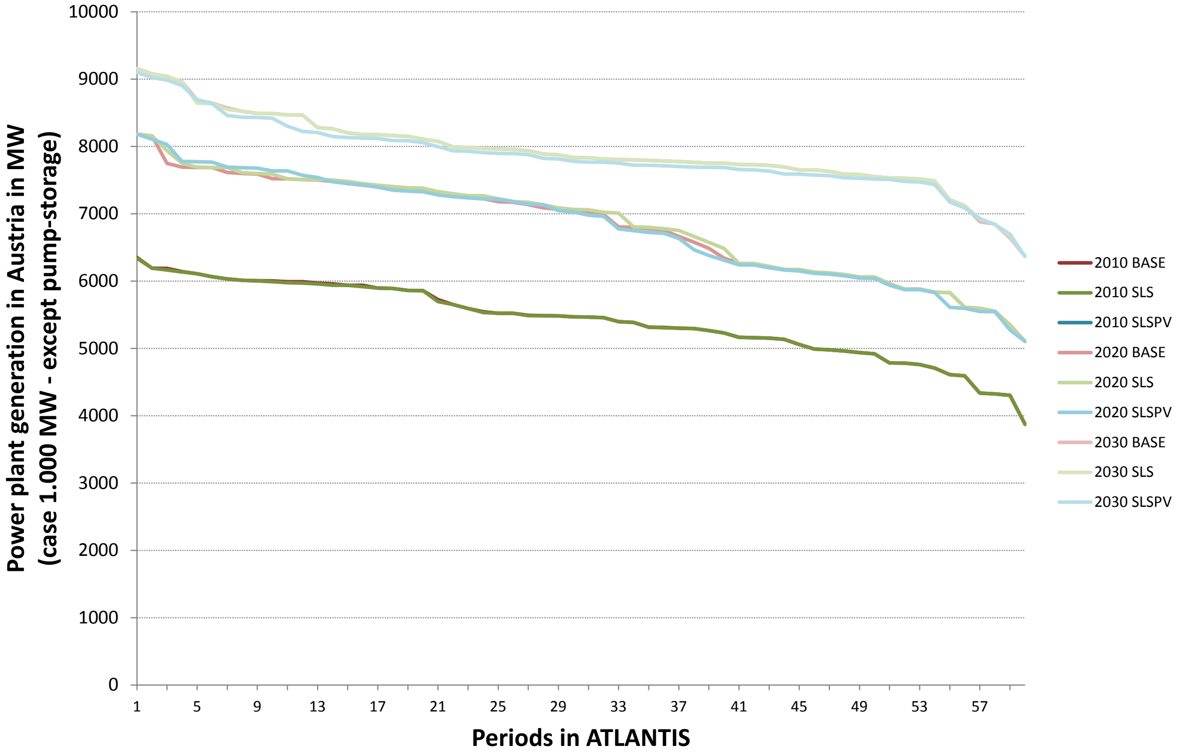


Figure 36: Overview of generating in Austria in case 1,000 MW (except pump-storage)

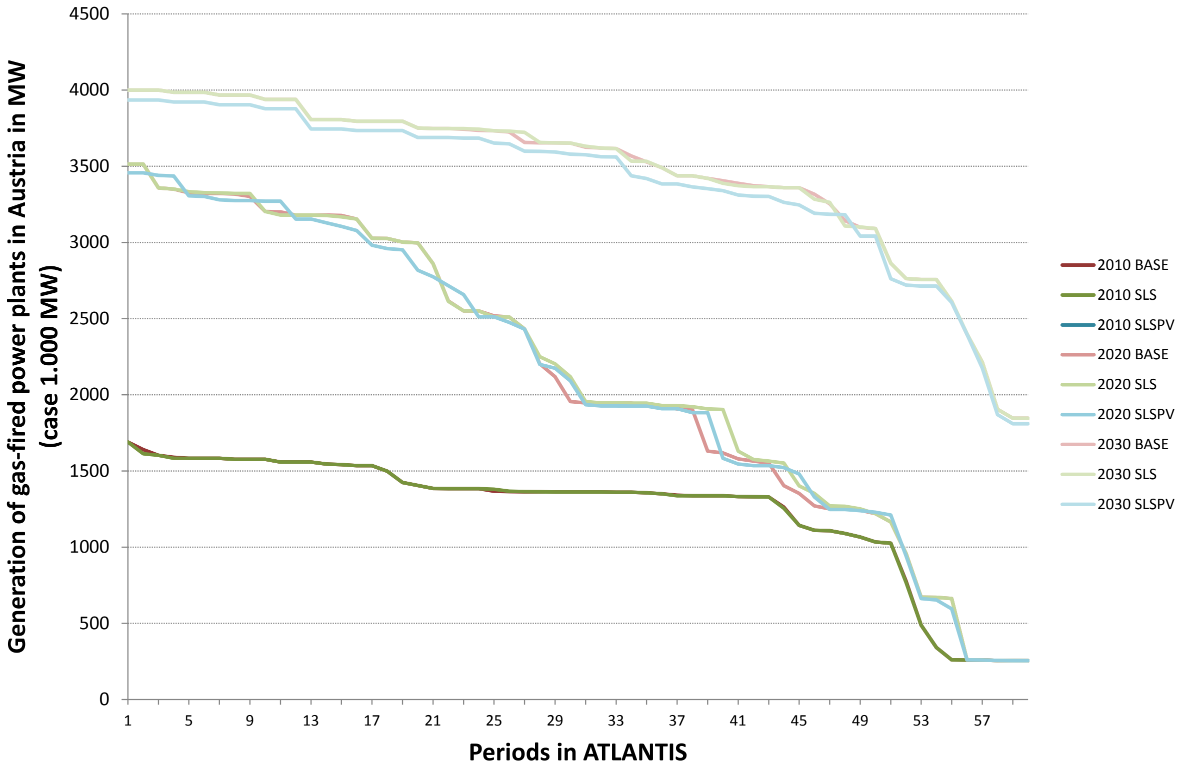


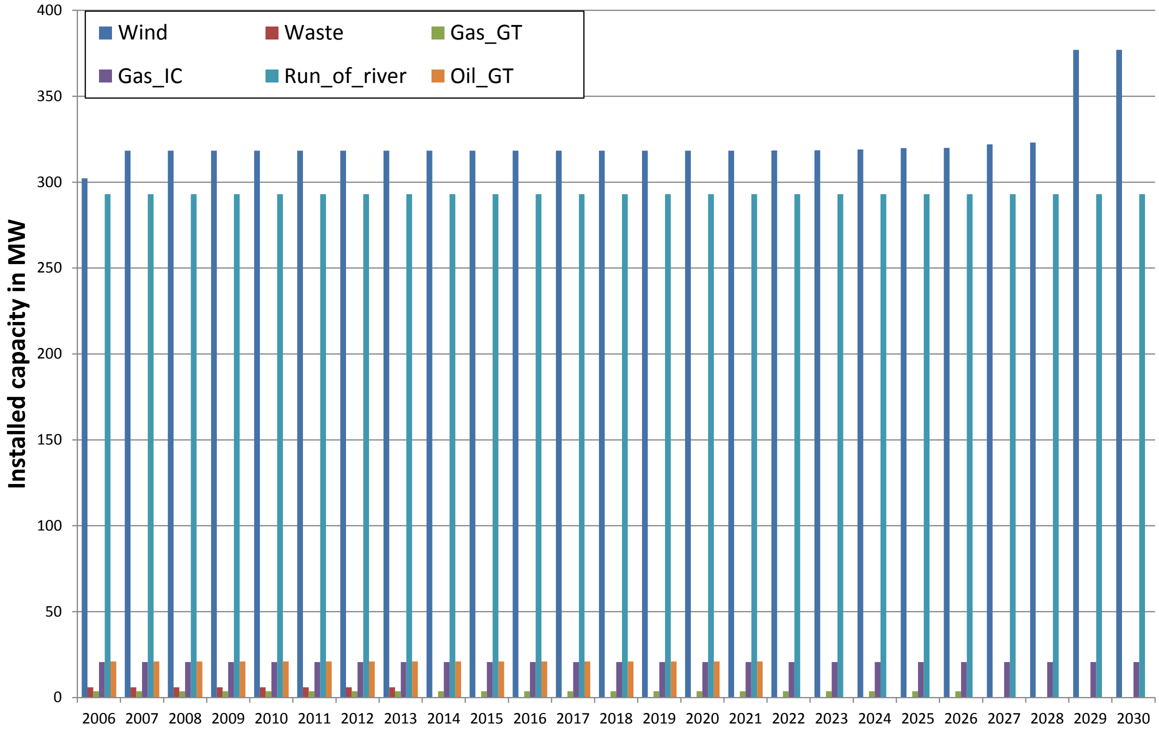
Figure 37: Generation of gas-fired power plants in Austria (case 1,000 MW)

Figure 38: Changings in import export compared to BASE case for SLS 1000 MW and SLSPV 1,000 MW

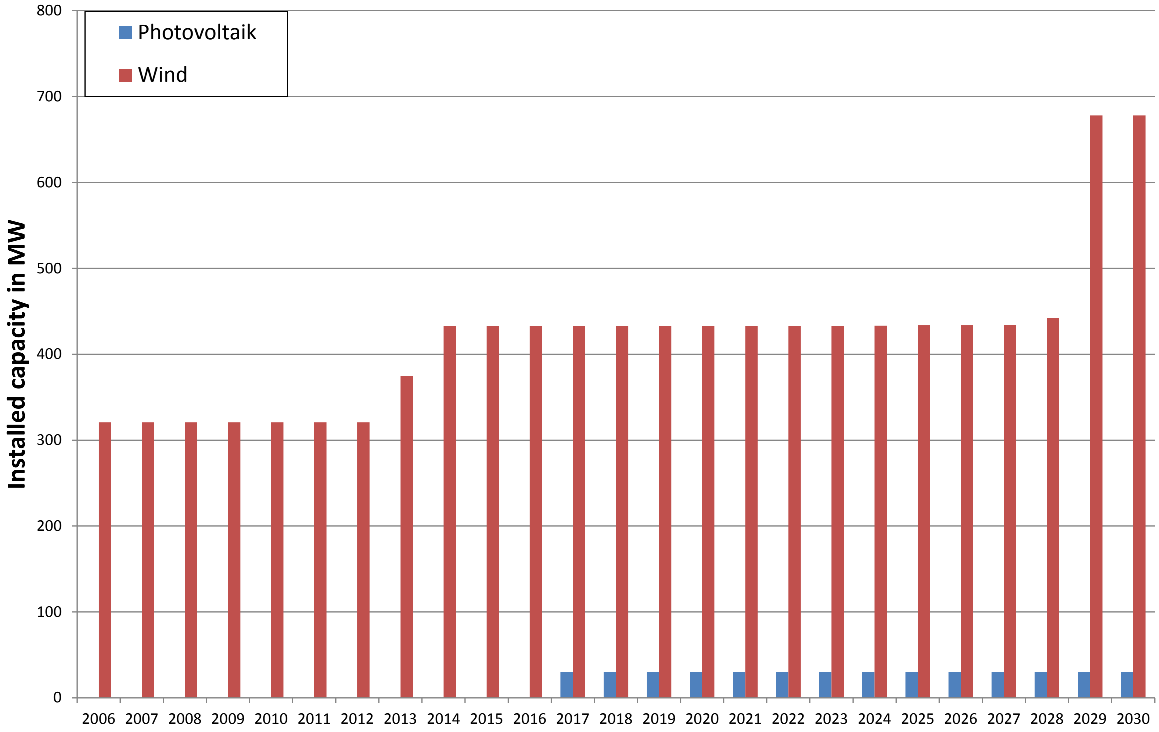
9.2 Additional information to application redispatch reduction

9.2.1 Generating structure of used nodes

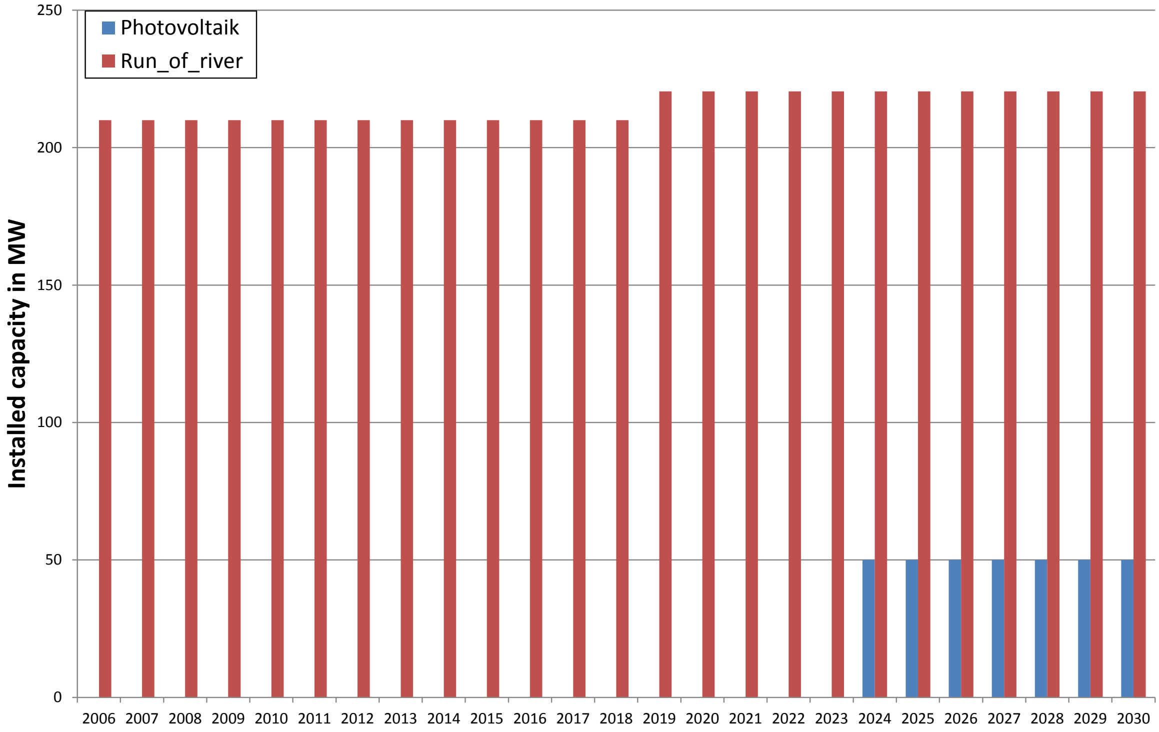
9.2.1.1 Node Bisamberg (220 kV)



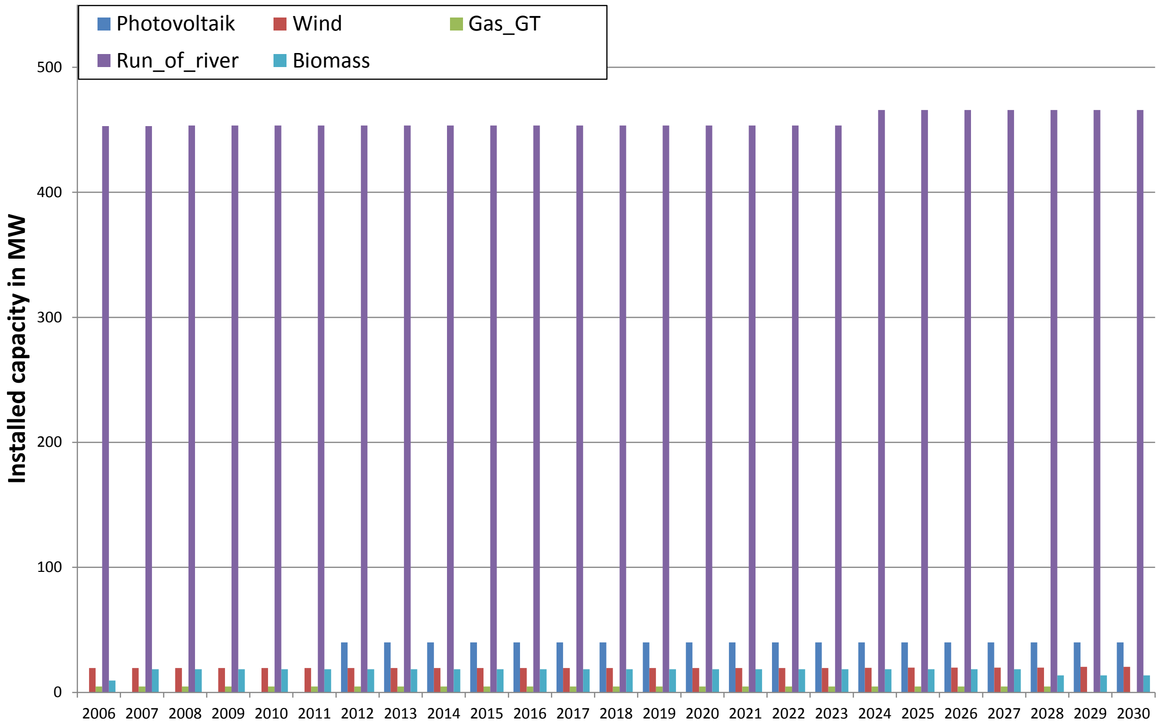
9.2.1.2 Node Stixneusiedl (400 kV)



9.2.1.3 Node Wallsee (220 kV)



9.2.1.4 Node Ybbsfeld (220 kV)



9.2.2 Redispatch variation by using DSM at different nodes (DSM potential 200 MW a day)

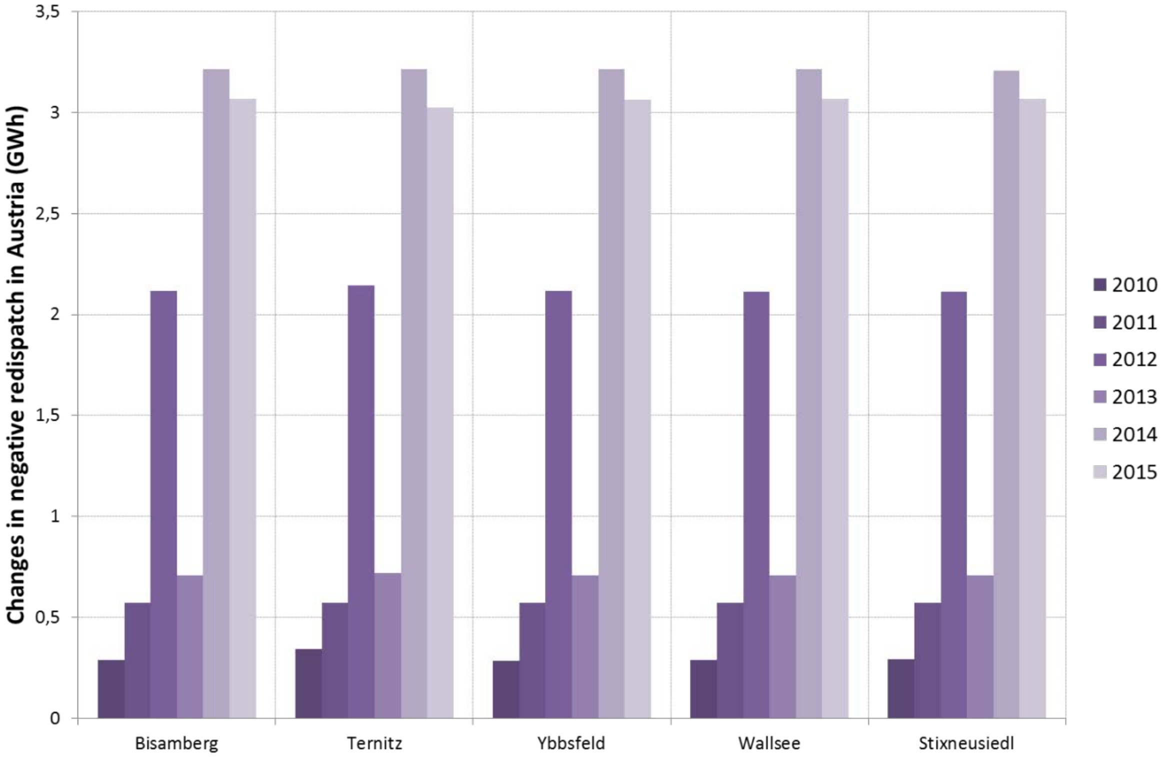


Figure 39: Changes in negative redispatch at different showcase nodes in Austria between 2010 and 2015

9.2.3 Reduction of CO_2 emissions (DSM potential 200 MW a day)

Figure 40: Reduction of CO_2 emissions in case 200 MW at different showcase nodes

9.2.4 Changes in generation in Austria (DSM potential 200 MW a day)

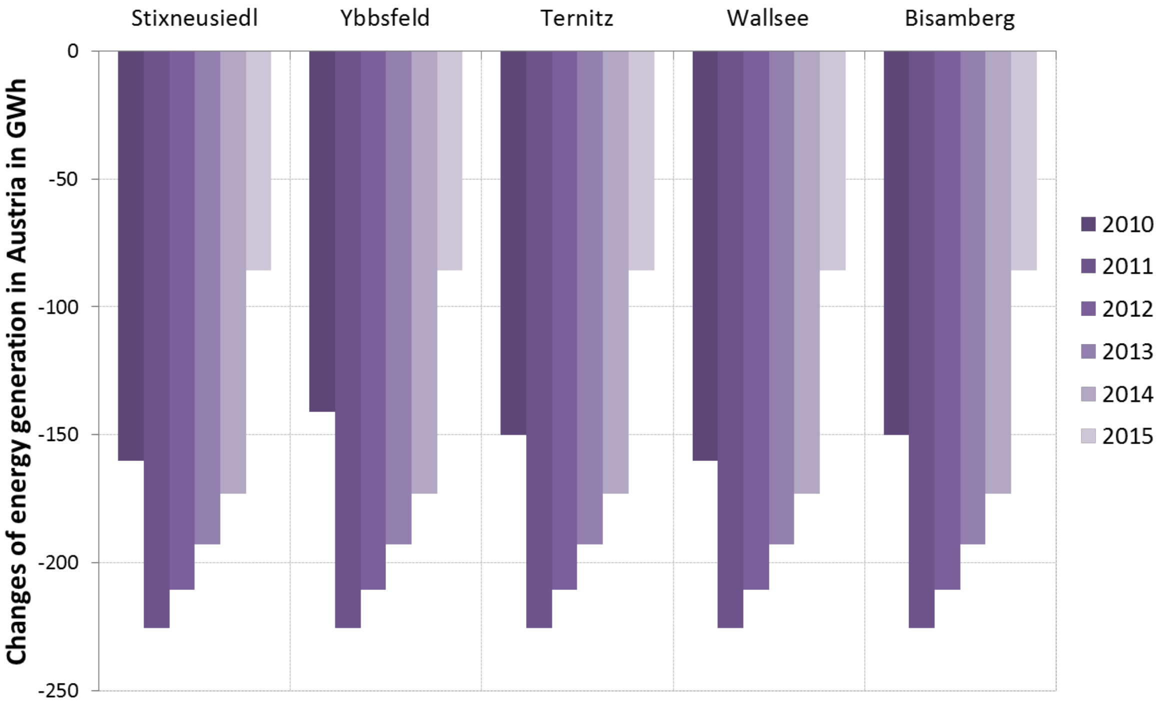


Figure 41: Changes in generation in Austria (all plant types) in GWh

9.3 Additional information tertiary control energy market

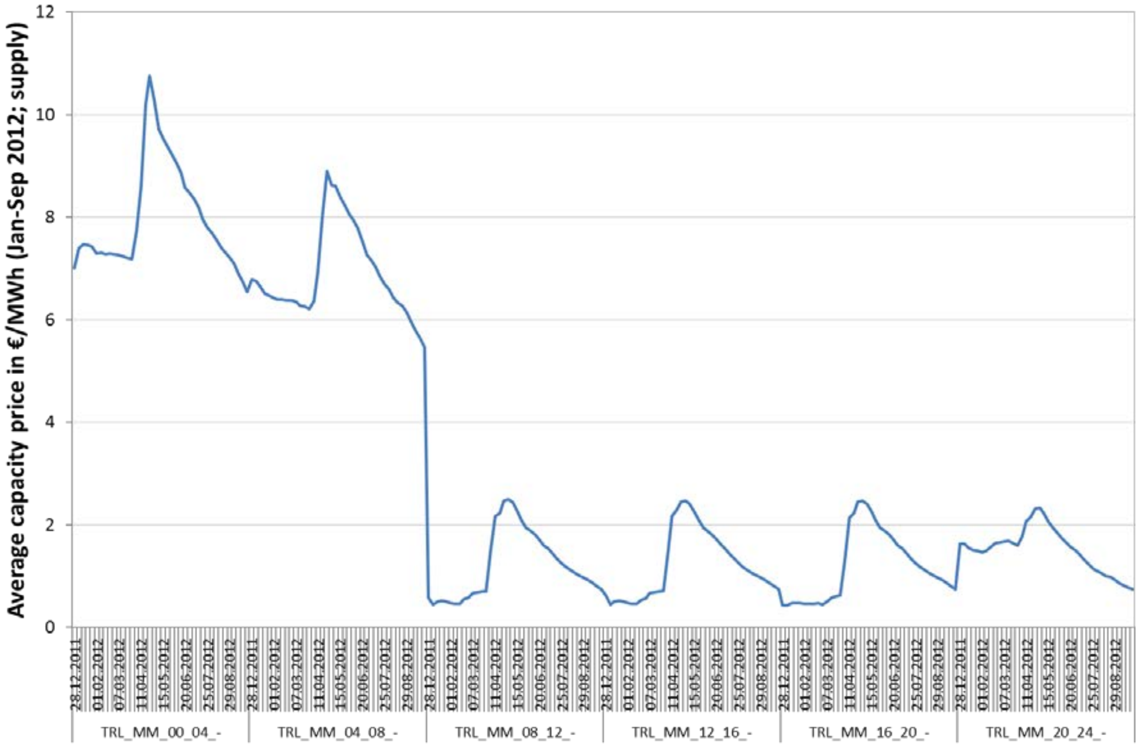


Figure 42: Average capacity price for the supply of energy/capacity (negative)

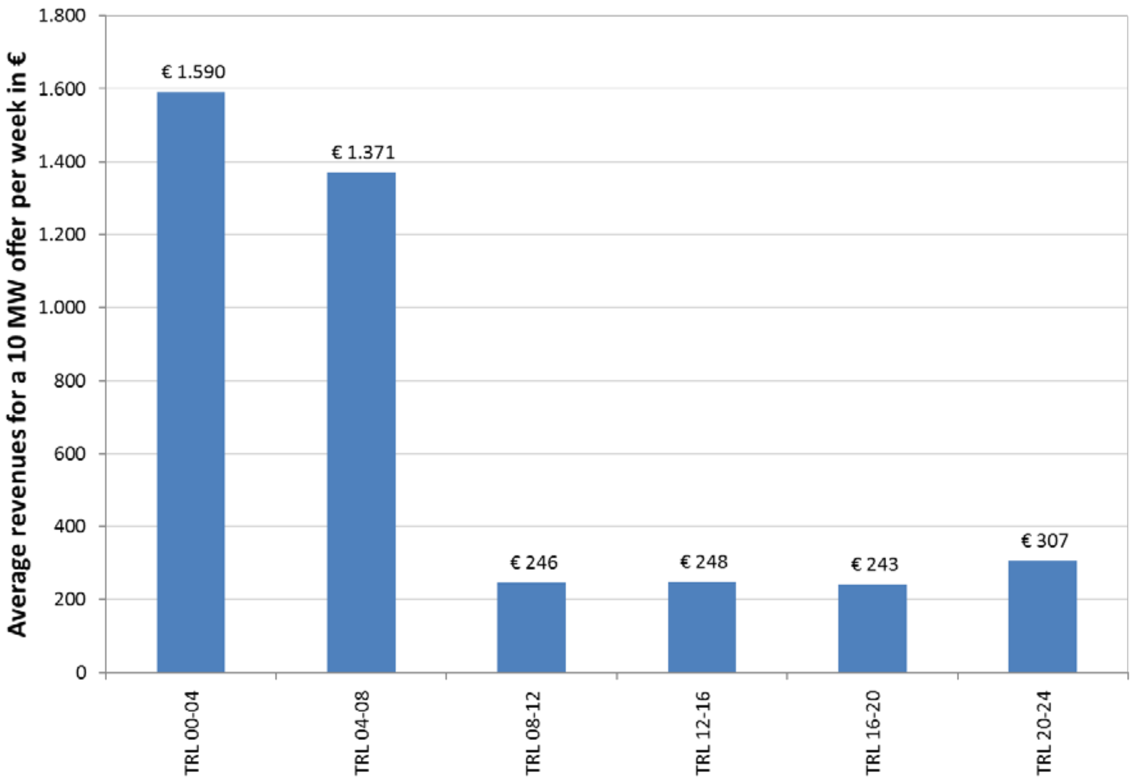


Figure 43: Average revenues for the minimum bid of 10 MW at negative tertiary control market (Mon-Fri capacity price)

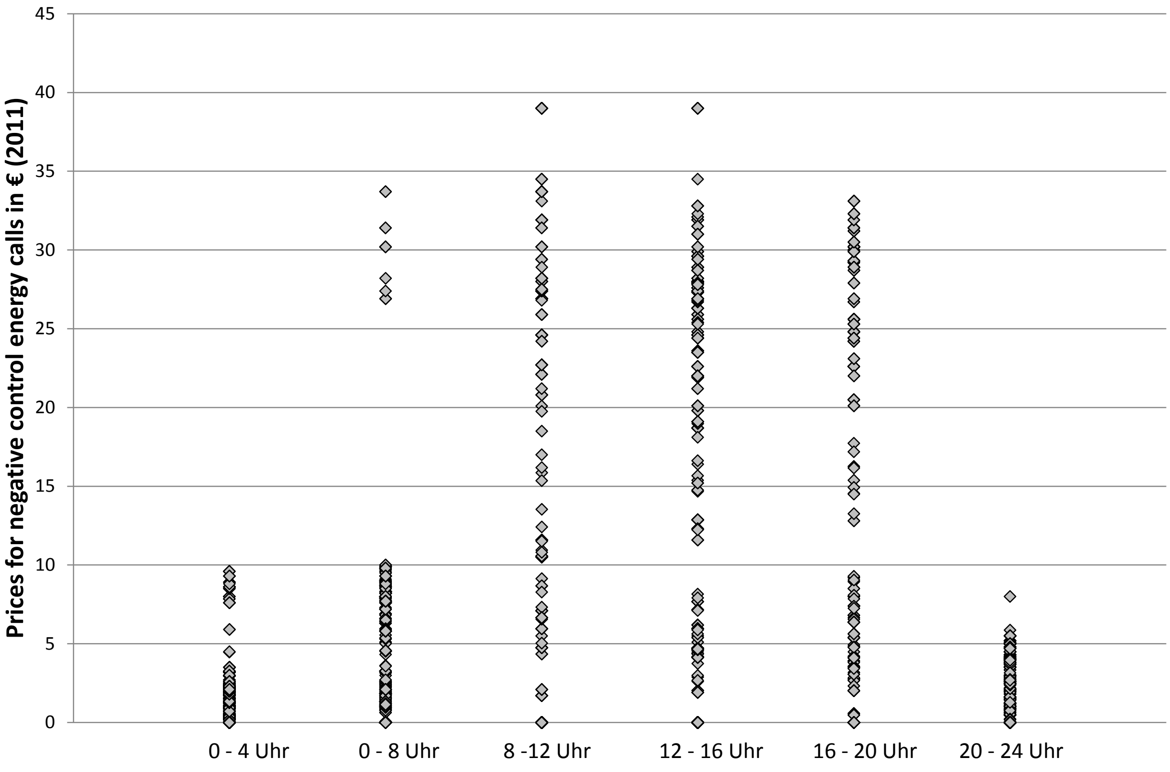


Figure 44: Price variation of negative calls 2011 (APCS, 2012)

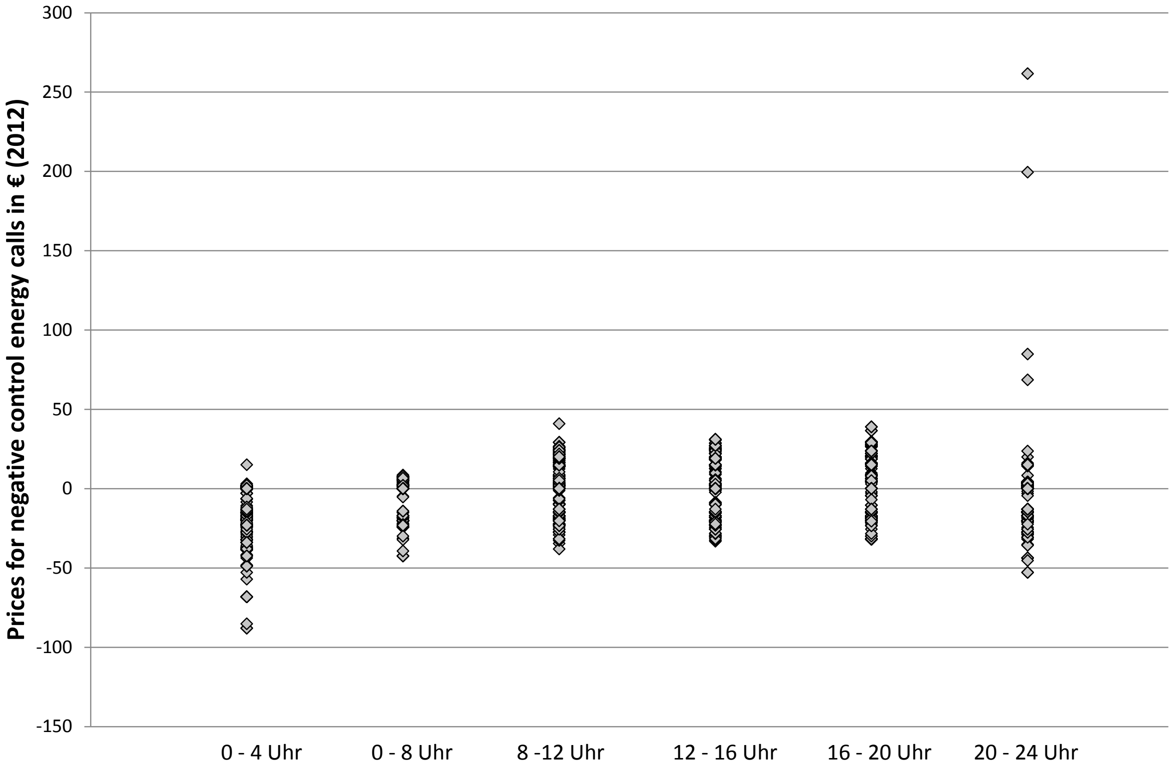


Figure 45: Price variation of negative calls 2012 (APG, 2012)[5]

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[5] As you can see from Figure 45 that is was possible in 2012 to use energy because of stability and get paid for this use (negative price as energy bid)

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