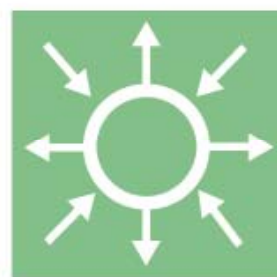




Market Design Project

Demand Response Resources in Sweden
– a summary

Elforsk rapport 06:41



Peter Fritz

June 2006

ELFORSK

Market Design Project

Demand Response Resources in Sweden - a summary

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Foreword

Despite having had a deregulated electricity market in Sweden for over ten years we still need to increase our understanding as to how deregulated electricity markets actually work and how possible problems are to be solved.

Several of the projects that Elforsk's Market Design program has carried out over the last five years are tied to the question of peak load capacity and opportunities for demand reduction within the Nordic electricity system. This report is an attempt to summarize the lessons learned this far.

Elforsk (Electricity research) is owned by the Swedish electricity industry. Its corporate business idea is to carry out research and development in line with the interests of the owner companies and carry out these research projects in cooperation with other parties on the market. The Market Design program was initiated in 2000 for the purpose of increasing the knowledge of how deregulated electricity markets work. The program is financed by Svensk Energi, EBL-Kompetanse in Norway and the Swedish Power Authority.

More information on the program, our reports and current activities is available on program's website, www.marketdesign.se.

Stockholm, June 2006



Peter Fritz
Program Secretary, Market Design
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Summary and conclusions

An important discussion in later years has been whether the necessary reserves in the electricity market are to be generated through normal market mechanisms, i.e. with the price as the primary controlling parameter, or if it requires a collectively financed capacity reserve and how regulations in such a case should be shaped. The issue is first and foremost a matter of where the line is drawn between that which ‘the market’ should handle and that which can be assured through regulation. Autumn 2002 Svenska Kraftnät (the Swedish TSO) presented an investigation to the government in which it was suggested that the capacity balance should primarily be managed through the use of normal pricing mechanisms, but that the state should strengthen responsibility for the nation’s capacity balance in the period up until 2008.

When approaching an effect loss situation, spot prices and balancing power prices will skyrocket. Today, most people are in agreement that a condition for maintained delivery safety is that normal pricing mechanisms are in place and that consumption actually is affected by high prices. The main reason for this conclusion is that it is very expensive to keep production facilities in reserve for situations that are expected to occur very seldom – it is cheaper to encourage large customers to reduce their consumption. The other reason is that increased price sensitivity creates conditions for a more stable and more predictable pricing development in strained situations.

While being aware that a response to increased demand is needed, we see too little of that on the market today. The aim of this project is to present concrete measures that will awaken this slumbering resource.

In order to judge how much demand response that can reasonably be expected and if there is any financial gain for customers, electricity suppliers and grid operators; it has been necessary to cast a few predictions about future price peaks. We estimate price peaks in the 3-10 SEK/kWh interval for an average of 40 hours per year.

Judging from the work presented in this report, it appears probable that there is a significant ability and interest among customers to reduce their consumption as long as the economic incentives are large enough. With price peaks we have estimated it should be possible to achieve demand response of around 2 000 MW, probably more. It must be made clear that this is not a persistent capacity reduction. What we have mainly focused on are the consequences of a price peak over three hours in the morning. A large part of this untapped potential lies in the many electrically heated family homes. In order to extract this capability, a large obstacle must be overcome. With the metering equipment we have today, and even the minimum required equipment after 2009, this group is of no interest.

In our report we have highlighted five different business models that can contribute to realizing the existing potential. They are clear concepts and relatively simple to carry out, as well as having the potential to provide economic benefits to all involved: customers, electricity suppliers and grid owners.

Perhaps the most interesting business model aimed at smaller customers is one we have called “Fixed price with the right to return” after a model by Trondheim Energi in Norway. If this model were to be launched widely to smaller customers instead of today’s “Take and Pay contract” it would open up for many new possibilities.

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Some of the resource material for this report comes from:

Elforsk report 06:16, Business models for increased demand response on the electricity market (Swedish only)

Elforsk report 06:11, Effect reduction by mid-size consumers (Swedish only)

Elforsk report 05:31, Customer reaction to peak prices

A number of seminars and workshops have been held where the questions have been analysed and the results discussed.

1 Introduction

1.1 Background

How to design the electricity market in order to assure a sufficiently high reliability of supply, even during the hours when the system is strained the most, has been discussed in depth over the last few years. The basic problem is that electricity, as most people know, can't be stored. It is a perishable commodity that has to be used the moment it's generated. When it's really cold outside, or when the system for other reasons has a great demand placed on it, there must be reserves. Those can be either in the form of generation plants or flexible demand.

An important discussion has been whether the necessary reserves can be created through normal market mechanisms, i.e. decentralized with the price as the main control parameter, or if it requires a collectively financed capacity reserve, and in such a case how the set of regulations should be laid out. The question is: where is the line between what the 'market' should manage and what it can be assured through regulation. This is a fundamental question in the deregulation debate. This is also why this issue is of such great importance in both practice and principle.

As in many cases the question isn't simply 'black or white'. The government, through Svenska Kraftnät (SvK), the authority responsible for system management, is already ensuring there are reserves in the system, but these, 1 200 MW, are intended for use in actual fault situations and not in the case of, for example, very cold weather. To expand this responsibility to also encompass reserves for extreme weather situations is not a major economic issue. The costs for the necessary extra reserves are around 0,002 SEK/kWh for every customer in the country. The problem, and we'll return to that, is to prevent collectively financed capacity reserves from becoming successively bigger by necessity, at the cost of what the market players themselves can and should take responsibility for.

In autumn 2002, Svenska Kraftnät submitted a report to the government where it suggested that the capacity balance primarily be achieved with the aid of normal pricing mechanisms, but that the state should strengthen responsibility for the nation's capacity balance during the period up until 2008. This resulted in a government bill allowing Svenska Kraftnät, during the period 2003-2008, to sign an agreement giving them the use of 2000 MW of production and reduction of demand as a capacity reserve. The Swedish state's expanded responsibility for capacity balance is thought of as a temporary solution aimed at giving participating players time to carry out necessary preparations and adjustments.

An important aspect of keeping a capacity reserve is that it is priced very high. The price will gradually reach a level of 15 SEK/kWh in 2008, in other words considerably higher than we've seen before in Sweden. The reason SvK sets the price of using the reserve so high is to give producers, electricity dealers and customers a reasonable

chance to solve the risen situation themselves – not until the market has failed shall the collectively financed reserve be brought online. From this perspective the capacity reserve is more like an alternative to enforced rationing in a crisis, and resource participants should count on it.

The aim with this project is to aid in preparing market players for a situation where the centrally administrated capacity reserves are minimized.

1.2 Demand response is a central part of the solution

One of the conditions for maintaining stable supply with normal pricing mechanisms is that customers become more active in price development.

The prime reason for this conclusion is that it is very expensive to keep generation plants in reserve for situations that are expected to occur very rarely. Generation plants have high fixed costs. In order to maintain their economic feasibility, a certain number of operational hours are required to offset costs and therefore keep their energy production from becoming astronomically expensive. But there are also costs associated with getting customers to reduce their consumption when necessary. To begin with, the customer wants to be reimbursed for temporarily reducing their electricity usage. Different measuring systems might be required as well as agreements and communication equipment to enable more flexible customers – all leading to extra costs.

The second reason customers should take a more active part in the price development is to create conditions for a more stable and predictable pricing development in strained situations. How should generators price generation that might only be in operation on an average of ten hours per year? Pricing to variable costs, as is the norm, doesn't cover the costs for fixed expenditures. Customer flexibility enjoys the advantage of low fixed costs as compared to low variable costs.

Due to various causes, there is too little flexibility in demand on the market today. So this is a future resource, but getting there will require significant efforts from several parties.

1.3 Market Design's demand response project is run in several partial projects

The project began spring 2005 and consists of several partial projects

1) Expectations regarding future price peaks

The risk of price peaks (and possible power cuts) is the basic driving force to get the market players to create capacity reserves. The aim of the partial project is to describe which price variations (price peaks) can be expected on the Nordic market in the future.

2) What the trials show us

The aim is to collect results and draw conclusions from Swedish and some Nordic projects regarding the possibilities of increasing the flexibility on the side of demand, as well as carrying out a complementary study about demand capacity of middle-sized consumers.

3) Analysis of market players and business models

Based on the results from point 1 and 2 we have made a description of what various business models could look like and which roles and economic incentives different players have in these business models.

4) Analysis of regulations

The partial project will answer the question of whether the current regulations support a development toward increased demand flexibility.

In conjunction with these partial projects, the international project “Demand Response” is run within the framework of IEA, in which Sweden and other Nordic countries take part. This project will carry on through 2006.

2 Conditions / driving forces for effect reduction

Prior to 1996, before the electricity law reforms, it was the larger generation companies that had the responsibility to ensure that there was sufficient capacity in the system. That could be done by expanding generation, negotiating with their customers about reducing demand or signing agreements with other generators. The generators did this voluntarily in return for a monopoly to deliver to their customers. The generators worked together to ensure that each lived up to its commitments. Since stable delivery is a collective matter nobody was allowed to get a free ride. (If we disregard grid problems, all customers have basically the same delivery reliability.)

2.1 Shape of contract determines who is affected economically by capacity shortage

After 1996 the producer monopoly was ended. Today, independent electricity suppliers can purchase power from the stock exchange and sell to customers. Generation, electricity trading and grid have gradually developed into different industries. Even in companies that have generation as well as trade, these two are separate divisions each with their own targets and goals and own business logic. The earlier connection between generation and reliable customer delivery is now broken.

For the generation companies, the emergency power plants, required prior to 1996, have become a costly burden. They're expensive to maintain and generate hardly any income as they're so rarely in operation. For the generators this type of production is associated with high risk – if there is a capacity shortage in the country and prices skyrocket there is money to be made, but for the rest of the time these plants are a business loss. To a generator these emergency power plants can be likened to a lottery ticket.

Today it's not the generators but the electricity suppliers and customers that have the economic incentives to make sure there are sufficient reserves.

If there is a capacity shortage, market prices, both at Elspot and Balanstjänsten (Svenska Kraftnät's market for balancing power), will most certainly become very high. If this coincides with unusually high consumption, which is likely, many electricity suppliers will be affected financially. The reason many electricity suppliers will be affected is that they, at least in part, purchase fixed volumes of power and sell "free volumes". A normal electricity agreement still looks like it always has – despite having a fixed rate there is no upper limit as to how much (or little) the customer may use ("Take and Pay" contract). However, when the electricity supplier signs power purchases contract with a fixed price, he must carefully specify volume. This results in a volume and price risk. The electricity supplier also carries the "power balance risk", i.e. the risk that the balancing price deviates greatly from the spot price.

Customers who buy at a variable rate, or larger customers who buy electricity using a combination of “physical” spot price agreements and financial price hedge contracts, carry the economic risk for capacity loss themselves. (As mentioned above, the electricity supplier still usually carries the power balance risk.)

If the situation gets so serious that customers are involuntarily disconnected from the grid due to capacity deficit, which has not yet happened in Sweden, it's the disconnected customers that will suffer. There are today no compensatory mechanisms in place for such an occurrence. Should this happen, the spot market and balancing service prices will still most likely be very high, which means that all who are exposed to the price and volume risk will be affected economically.

Electricity suppliers as well as customers can take certain steps to lessen their risk exposure. One alternative for the supplier is to stop selling “Take and Pay” contracts. Another is to sign agreements with producers for the purchase of power at a predetermined rate when approaching capacity deficit, a third alternative is to negotiate with customers about buying back power when the price is sufficiently high. The customers, on the other hand, can reduce their risk exposure by being prepared to reduce their demand when the price is at its highest.

Another problem today is the “profiling” is used for all smaller customers. Neither the electricity supplier nor the customer has any economic interest in trying to reduce the demand as long as the customers' consumption isn't measured with hourly resolution.

Another problem - so far we haven't experienced any real high price spikes in Sweden. It's hard for electricity dealers and customers to feel motivated to take on costs in preparation for a situation that has not yet been experienced, particularly when the situation is expected to occur very seldom. Some are, no doubt, still hoping someone else will solve the problem and make sure that capacity shortages and high prices don't occur.

2.2 The most important driving force is the risk for price peaks

In spite of today's temporary solution, where Svenska Kraftnät purchases up to a maximum 2000 MW of extra capacity, there are no guarantees against high prices – quite the reverse. SvK applies a pricing to these resources that means today's price is at least 8 SEK/kWh should these reserves have to be used. This price will gradually be raised to reach 15 SEK/kWh in 2008. A collective capacity reserve such as the one we have is consequently not a protection against high prices, but the risk of consumers getting disconnected because of capacity shortage will naturally be reduced.

How often do we expect price peaks to occur and how high will they be?

To begin with we want to emphasize the difficulties in giving a clear and substantiated answer to this question. Since we have a system with relatively good generation reserves we can't base our estimation on historical price statistics. If we did that we'd

find there have been very few price peaks. A possible way to move forward is to simulate the occurrence of price peaks in a model world. However, we have not had access to such a model in this project. With model simulations there is a certain risk of ‘steering’ the results through choice of input data, in such a way that nothing is actually learned.

What we have done instead is to make use of a qualitative effort. We have simply asked ourselves which price peaks are necessary to get the market players to spontaneously and in a profitable manner put up necessary reserves, either as generation plants or as reduction in demand.

By price peaks in this context we mean price levels that are no longer decided by variable production costs in a fossil fuel power plant. With today’s oil prices this price level is at 2 SEK/kWh. In economic theory, prices above that level are usually referred to as costs for shortage and should ideally be determined by the demand side, i.e. the price level when a sufficient number of customers refrain from buying a product of service. In other words the price, not the administrative rationing system, should match demand to availability of capacity.

One way of approaching this issue is to wonder about which prices would be required to make a profit by keeping generation in reserve.

Example:

Let’s assume the cheapest reserve generation plant costs 150 SEK/kW/year (about half the cost of a new gas turbine). We’ll also assume the variable production cost is 2 SEK/kWh. With an expected operational time of 40 hours/year it will require electricity prices on an average 5 SEK/kWh during these 40 hours.

If we imagine the extreme exception of having a generation facility in reserve that is expected to be in operation for one hour per year, it is obvious the price during that hour must be astronomically high to make it profitable – a price level of 150 SEK/kW is of course not reasonable. For a house owner with electrical heating, this would amount to an extra cost of 1500 SEK just for that hour.

Conclusion:

If price peaks on an average 5 SEK/kWh occur for an average of 40 hours per year we can finance production that can handle all but the 40 worst hours.

The next question is whether we believe price peaks on an average 5 SEK/kWh for around 40 hours is also enough to create sufficient action from customers to manage the capacity balance during the 40 most critical hours?

Consumption peaks in Sweden occur when it’s cold outside and industry and business in general are fully active. If we look at the national capacity outtake in the country over a 10-year period we’ll see that the demand during the highest hour is around 2000 MW higher than hour “400”. If demand reduction is to manage the capacity balance for an

average 40 hours per year the highest demand peaks must be cut by approximately 2000 MW. In other words, the price peaks must be high enough to cut the demand peaks by 2000 MW.

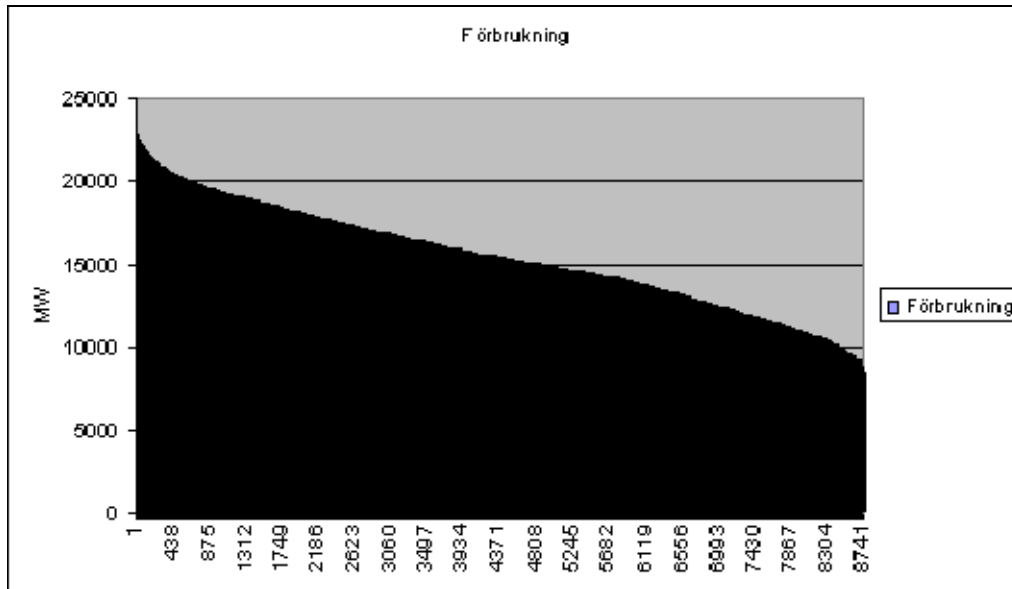


Figure 2.1 Accumulated customer capacity outtake over a 10-year period.

With our way of analyzing pricing development on the market, the price level is determined by the costs of activating physical resources. Under normal conditions it's the variable production costs at the most expensive power plant that determine the prices and during price peak periods, the compensation customers want for temporarily reducing their electricity usage. Without getting ahead of the results in this study, in working with this project we have presumed that prices in the 3-10 SEK interval for an average of 40 hours per year is enough to achieve a 2000 MW effect reduction. In the next section, we will return to which customers we believe have this flexibility in their demand.

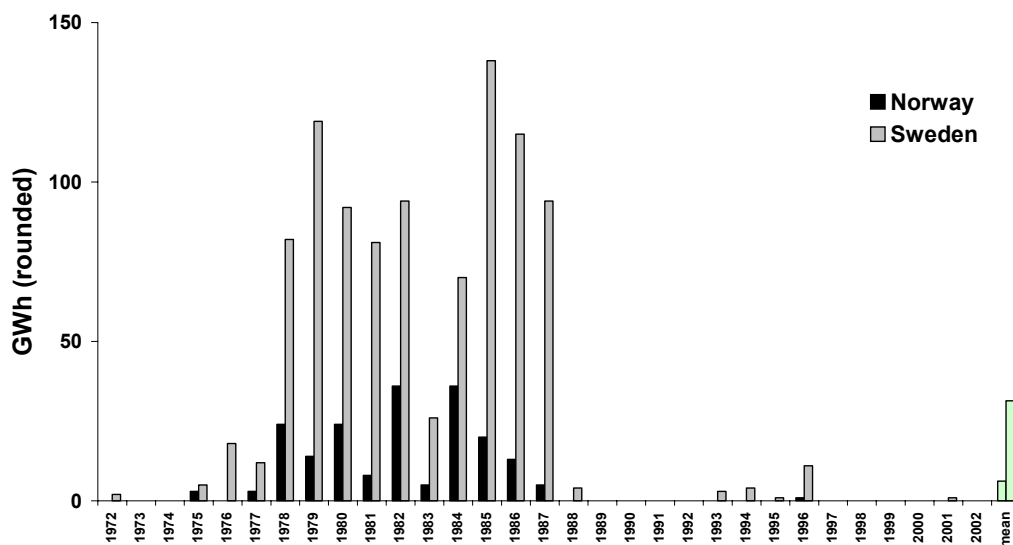


Figure 2.2 Simulated capacity loss situations 1972-2003, given today's production and demand situation.

It is important to point out that the price peaks will not appear regularly. It is not even certain that we will see price peaks every year. The diagram above shows that we have a period of very mild winters behind us. But we suffered very cold winters in the mid-80's.

It is conceivable, and even probable, that in the future we will see situations with even higher demand peaks than those shown here. In such instances it might require other measures to manage the capacity balance than high prices, such as requesting the population to be more economical with electricity or even use rationing. It might also be a good idea to maintain some form of capacity reserve for extreme situations. Such a reserve could be useful not only in cases of extreme weather but also as an extended interruption reserve should accidents occur in generation plants or in main grids. If it is necessary to have a "crisis reserve" over and beyond the current Interruption reserve, despite functioning market mechanisms, is not something we're looked deeper into in this project.

One driving force for demand response is the risk/possibility of price peaks. An assumption for the continued work is that we will see price peaks in the 3-10 SEK/kWh for an average of 40 hours per year.

2.3 Other driving forces

The main driving force for customers can be expected to be the lowering of costs of electricity, i.e. economic incentives. American trials show that economic gains are the

most important for customer participation, but factors such as environmental benefits also play a role.

For the grid companies, a driving force is a lower capacity demand in their grids, thus reducing needs for investment and giving lower costs to main grids. It can also be about developing and selling different services to one's customers or to the electricity suppliers that operate in that area. In addition to this there can be, as for the customers, an interest in acting in such a way that it contributes to a better working electricity market, for example by investing in better measuring equipment than the law requires. Demand response, as mentioned earlier, gives benefits to the market's way of operating that can be hard to catch. It could be things like reduced possibilities to exercise market power, incentives for innovation and increased efficiency on both sides, generation and demand, responding to the market's signals. In addition, the right technical solutions can lead to more effective handling of metering and settlement.

3 Potential - experiences

3.1 Market Design's demonstration projects¹

During the winters of 2003 and 2004 we demonstrated the effects of confronting households with electrical heating with electricity prices in the 3-10 SEK/kWh interval. The aim was to investigate the price sensitivity of customers with different heating alternatives. Previous trials have indicated that the price sensitivity of households is small. However, these trials have been carried out with considerably lower price differences than the extreme price levels expected in a future capacity loss situation.

The first winter's trials with the local distribution company Skånska Energi yielded very interesting results. The trial was therefore extended for the second winter season with additional customers from Skånska Energi. The distribution company Vallentuna Energi was also tied to the project. In total for the 2004/2005 winter season, 53 Skånska Energi customers and 40 customers of Vallentuna Energi took part.

For the trials, a special pricelist was constructed. The pricelist allowed the electricity supplier to apply a higher electricity price for a maximum of 40 hours. For the rest of the year the customer receives a deduction on the regular price. The higher electricity price lies in the 3-10 SEK per kWh interval. Notification is given to the customer via text message or e-mail on the day before as to the time and level of the high price.

The pricelist is constructed to create cost neutrality relative to the ordinary pricelist if the customer doesn't take any action. If the customer does take measures, the electricity bill will be smaller. In an example from Skånska Energi, the customer offer of 1400 SEK per year could be saved if electricity consumption was reduced by 75% during the high price instances. In the Vallentuna Energi trials in the winter of 2004/2005, the promised level of savings was dropped to 1000 SEK per year to investigate customer interest even at a lower rate of savings.

Along with the customer agreement, tips were given on how to temporarily reduce electricity consumption and which measures are suitable depending on heating systems and alternatives.

The technical results, questionnaires and in-depth interviews show an unambiguous and consistent picture, that customers generally have considerable interest, ability and persistence when it comes to reducing electricity consumption during instances of high prices. The load was reduced by an average of no less than 50% at times of high electricity prices.

¹ Read more on this in Elforsk report 05:31

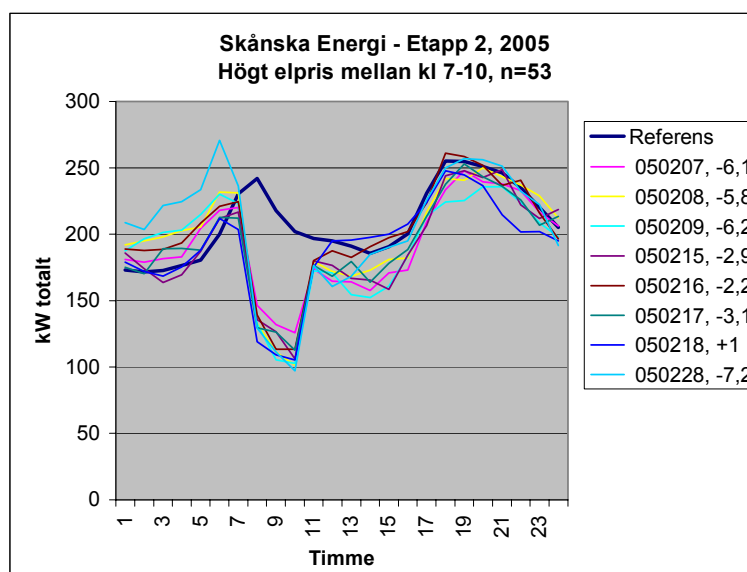


Figure 3.1 Examples of results. The curves represent different days with high prices, the numbers on the right show the outside temperatures at the date in question.

Another important conclusion from the project is that the results were attained without having to install any technology on the customer's end (they were already equipped with hourly metering). The results also show great similarities between the years and the respective electricity suppliers' customers.

The interviews carried out can be summarized in the following points:

- ✓ It is felt that the trials have gone well.
- ✓ The motives for taking part vary; it was economically profitable, it was both economically profitable and interesting, it was good from an environmental perspective, it was a challenge to see how much one could reduce power usage.
- ✓ It was not viewed as troublesome or time-consuming to affect changes.
- ✓ No major drawbacks were experienced in connection with bringing down electricity usage.
- ✓ The level of profit wasn't that important, rather it was about doing something beneficial for the environment.
- ✓ All types of deductions are important.
- ✓ Despite many not having a grasp of how much they saved, they were happy with the trial.
- ✓ A continuation with this type of tariff was viewed positively.
- ✓ Households were ready to finance and install some form of control equipment themselves.
- ✓ Large-scale application was not viewed as likely to present any major problems.

We have not had the ambition to up-scale this trial to a national level and evaluate how big a load reduction we could achieve if all customers with electrical heating received this offer. One reason it's not possible is that this agreement form is not attractive enough for the electricity supplier (more under section 4). However, the positive

response we received indicates that if a business model can be found that is interesting to all parties, this customer segment offers a huge potential. A rough estimate brings the consumption of electrically heated family homes to 10 000 MW when the electricity demand is at its highest. With prices around 3-10 SEK for 40 hours per year, a potential of 10 – 20 percent of the maximum outtake is not unrealistic.

3.2 Demand response capacity of mid-size consumers

Experiences from the interview study

The object of this study has been to evaluate the conditions for capacity reduction among mid-size electricity customers. Around forty companies have been interviewed over the telephone regarding their possibilities to carry out a demand reduction. The companies interviewed represented a variety of business areas; iron, steel, forge, heat treatment, chemical, foundry and foods. Large property management companies have also been interviewed as well as two real estate management companies and one school property management company.

The study has also made a closer analysis of three chosen areas; freezer storage, real estate companies with shopping malls and companies with surplus capacity. Finally, the total potential for the investigated areas has been estimated.

In total, the potential of the analyzed areas is estimated to be between 300 and 340 MW. Property management accounts for approximately 200 MW. The large potential within real estate management is relevant because here demand reductions can be achieved by changes in surrounding systems at a low cost. Through reprogramming the control and guidance equipment, the start of ventilation units can be shifted one to three hours. From a technical and organizational point of view, this measure is a simple matter. The demand reduction achieved per unit is limited, but there are a greater number of units, which create a large total potential. Even in freezer storage there are excellent possibilities for demand reduction by reprogramming control systems. The total potential for freezer storage amounts to 20 MW.

The demand reduction potential in the business areas studied is estimated to be between 90 and 130 MW at boom times and in times of recession respectively. The potential is partially dependent on the economy, since a large part of the identified demand reduction possibilities within the business sectors has to do with taking advantage of surplus capacity or temporary free capacity by carrying out short stops or delay starts of a process by one or two hours. This primarily concerns the iron and steel industries, but also the chemical and food industries.

The reason the demand reduction potential is largely limited to taking advantage of free capacity, is that the price model used in this study does not allow for reductions that result in loss of production, investments or moving job processes off normal working hours. The price model means that electricity prices will be between 3-10 SEK per kWh for about 40 hours per year. The profit from demand reductions is not certain using this

model, since it is dependent on how often the price peaks occur. This unreliability makes companies less inclined and prepared to change processes and procedures, which are often necessary to bring about a demand reduction.

What was interesting in partial project 3 was when the conditions for load control in industrial settings were examined and demonstrated.

Experiences from Market Design's demonstration project²

Six industries and their electricity suppliers took part in the project. In the winter of 2003/2004 these companies were Frigoscandia, Kinnaredssågen and Agrippa. In the following winter, 2004/2005, the companies Karlshamns, ITT Flygt and Rörviks Timber were added. High price was notified on one occasion in January and one occasion in February, in both years.

The results show that the relatively large industries, Karlshamns, ITT Flygt and Frigoscandia were capable of reducing their demand by on average 1 MW each, on the respective control occasions. Agrippa Manufacturing reduced their demand on two of the occasions by a quarter of their subscription. At other times the company stated that the state of production didn't allow for control. As for the participating sawmills, the consequences of a hurricane-like storm (Gudrun) made it difficult to carry out the trials. Following completed trials, each of the participating companies said they took a very positive view of future possibilities to control demand during one or two hours at temporarily high spot prices.

The conclusion to be drawn from the project is that industry is a heterogonous group with separate conditions for demand control depending on greatly varied industrial processes. Demand control is primarily suitable for industries that have thermal resistant products or a buffer capacity in their production. Demand control that causes loss of production or major re-planning of personnel resources will of course involve higher price peaks.

3.3 Demand reduction in electricity intensive companies - Industribud

In order to convince industrial corporations to carry out load adjustments during high electricity prices, Svenska Kraftnät and Energimyndigheten (Sweden's Energy Agency) initiated the project Industry Offer in 2001.

The concept entails letting the companies make an offer to their electricity suppliers stating how much they're prepared to reduce their demand and to what prices they're prepared to do this. Procedures for this and the dividing up of the economic result are regulated by a special agreement developed within the project.

Industribud has visited around 20 industrial corporations, seven balance responsible companies and also one heating company and four county councils. Beyond that, 30

² More on this can be read in Elforsk report 05:31

industrial corporations have been contacted where the possibilities for demand reduction was said to be low. So far the visits have been concentrated to industrial corporations situated in the southern and middle parts of the country.

At these company visits, potentials of around 900 MW in demand reduction and approximately 100 MW in increased electricity generation have been identified. The figures include the 350 MW demand adjustments that can already be activated at price peaks. Most of the measures could be in force for an hour, but 10-20 % could last from a couple of hours to a full day. In order to reach the full potential, very high prices are required (approx 13 SEK/kWh). In other words, we're looking at very high prices to achieve this high level of demand reduction with industrial corporations. For prices up to 10 SEK/kWh, this project estimates the potential to be 700 MW.

To get upper management to prioritize production cutbacks before other projects is of course a problem. One difficulty that can't be avoided is the work required within the company to join Industribud. Procedures and organization must be prepared, a supplementary agreement has to be negotiated with the company responsible for keeping the power balance and a bidding strategy has to be drawn up.

3.4 Other experiences

Emergency power

In connection with Svenska Kraftnät's purchase of resources for the extended capacity reserve, two players have placed a bid that means emergency diesel power units will start when Svenska Kraftnät calls for it. The price at which this has been bid indicates that this is clearly an interesting alternative. In a study recently completed for the National Energy Administration, the total emergency power capacity in the country was estimated to 1600 MW. If we assume 20 % of this capacity can be used in situations of capacity loss, we're looking at a capacity of 300 MW.

Direct control

In another demonstration project within the framework of Market Design, direct control of electrical heating and water heaters was demonstrated with customers that have central control equipment attached to their electric heating system. The demonstration trial aimed to verify controllable load of the direct electrical heating and water heaters, and to evaluate how the customers are affected by demand control during cold weather. Deals were signed with 50 of Jönköping Energi's customers participating in the project. The deals have been signed to a low level of customer compensation, - 300 SEK per year. The customers are situated under the same grid station and installed measuring equipment that measures in six-minute intervals.

The electrical heating was lowered remotely by 67 % between 8-10 am on five occasions. The occasions were days when the outside temperatures were expected to be

at the lowest. On one occasion, January 22nd, 2004, the outside temperature was 15 degrees below freezing at the time of control.

One experience gained from the trials is that the installations carried out in the early 90's still work and the demand control during the winter of 2003/2004 has shown an average controllable capacity of 4-5 kW per family home at 10-15 degrees below freezing. No customers have complained about the heating during the control instances.

3.5 Conclusions

The run-through in this section suggests the presence of a fairly considerable ability and desire on the part of the customers to reduce their consumption provided the economic incentives are substantial enough. With prices in the 3-10 SEK interval for an average 40 hours per year, it should be possible to achieve demand reductions in the order of 2000 MW, maybe more. It should be emphasized that this is not a lasting reduction. What we have focused primarily on is a price peak over three hours during the morning.

A large part of this potential is in the many electrically heated family homes and, no doubt, among other customers with electrical heating. In order to realize this potential, certain things have to change. With the metering equipment we have today and the equipment that is the minimum requirement after 2009, the economizing of effect in this group is of no interest. Within the project we have, however, understood that most grid owners are now investing in more advanced metering equipment than the law stipulates. In order to reach the large demand response recourses found among smaller customers, hourly readings of these customers are required, as well as hourly settlement.

In the next section, "business models", we focus on business models aimed at smaller customers counted on hourly readings being introduced for almost everyone.

4 Business models

This section aims to map, illustrate and describe possible business models for demand flexibility. The aim is to study which possibilities, incentives and obstacles there are to get different market players to suggest and contribute models that are practically applicable.

More on this can be read in the report “Business models for increased demand response on the electricity market”, Elforsk report 06:16. (Swedish only)

4.1 Analysis of players

There are three groups of players who are vital for increased demand response on the electricity market in various ways. These three groups are:

- Customers
- Electricity dealers/balance responsible companies
- Grid owners

In addition, we’ve identified a new type of player on the market, namely the aggregator of emergency generation.

The *customers’* participation is of course vital in achieving any kind of demand response. These must either respond to price signals of their own accord (manually or automatically) or at least let their supplier (or grid owner) take measures that affect consumption when this is requested. The main driving force for the customers is the possibility of saving money. Studies from the USA show that the economic incentives are by far the most important to convince customers to join various programs for demand response, but a desire to contribute to something good for society is not without importance.

With the price assumptions that have been used in Market Design’s various projects, i.e. around 40 hours at an average 5 SEK/kWh, about 15 % of the yearly total energy cost on the whole market will come from these 40 hours. This calculation is made with the assumption of an average electricity price of 0,25 SEK/kWh. With today’s high electricity prices the share will be lower.

Different models require varying degrees of commitment from the customers. Direct Load Control only requires that the customers approve the encroachment, but after that they can be passive. The same applies more or less for other types of automated solutions, even though they can be adjusted more easily to the customers needs. The greatest level of commitment from the customers is required in the cases when the customers must take action themselves. In the latter case it’s possible that the time at which a reduction in demand commences will greatly influence the response from the customers. This applies in particular to models aimed at domestic customers, who can

be expected to have far greater possibilities to affect their consumption in the pre-noon hours (for example by lowering their thermostat before leaving for work), whereas the possibilities ought to be fewer if the peak of consumption occurs later in the day, given that a large number of the customers are not at home at that time.

The *electricity suppliers* are the second group of great importance. The primary benefit for electricity suppliers ought to be connected to a reduction of the risk, i.e. a lower variation of the result rather than an improved expected result. In other words, this is based on the electricity suppliers having some degree of risk aversion. It is our estimation that it can be of particular importance to avoid very poor outcomes that can result in the company going bankrupt. Further, it's possible that different types of electricity dealer companies have different degrees of risk aversion. Electricity companies with considerable generation capacity of their own can to a high degree have internal "hedge", rendering it less exposed to risk and therefore possibly less inclined to introduce business models that reduce the risk. By offering types of agreements the customers are interested in, the electricity dealers can widen their margins. The effects of the suggested models/types of contracts are described more closely for each business model.

The *grid owners* are a third group of importance. The grid owners can have a number of incentives for wanting to bring in increased demand response. To start with, a reduction in the maximum demand can reduce the costs of subscriptions to grids. The subscription cost is on the order of 200 SEK/kW. One important problem here is that in grid regulations, as expressed in the Nätnyttomodellen (the Network Performance Assessment Model), costs for master grids are passed straight on to the end customers. Thus, profits from reductions in subscription costs do not necessarily bring any profit to the grid owner. The other driving force is that a lowered demand can reduce the need for strengthening one's own grid. To what degree this is important will of course vary from grid to grid. Further, the grid owners can sell services to other players, such as readings or demand control services.

But the grid owners' most important contribution is to ensure that the necessary infrastructure for meter readings is in place. The requirement for meter readings for the smaller customers is however limited monthly readings (from 2009) and to give the grid owners incentives to invest in better systems, from this perspective, than the law requires, the grid owners should have the option to take charge for this service, or get financing from the grid tariff.

4.2 Business models

The starting point is to get the customers to respond to the ordinary market's signals and not to create a system to drive the demand side to contribute as a quick interruption reserve. Direct load control and price response are both possible alternatives.

Five different business models have been identified as particularly interesting. We have worked from three main criteria when selecting models and the closer development of these are:

Effect: The model is to give the customers incentives to reduce their consumption at times when it is requested.

Economy: The model must have the conditions to generate a positive economic result for all parties involved.

Simplicity: The model must be simple and understandable for those involved. Costs for administration etc. must not be prohibitive and troublesome effects on compensatory systems and the like must be avoided as much as is possible.

The first criterion has meant that models such as normal time of use tariffs have been excluded. These don't give the customers specific incentives to reduce their demand at the really high price peaks, only the incentive to shift consumption between general high load and low load periods. The economical criterion is based on the model having the conditions to be profitable for the parties involved. However, this is not only about the expected outcome, but how it affects the risk for various players can be equally important. The third criterion has been simplicity, focusing on the customers wanting agreements they can understand and whose effects are reasonably predictable.

Of the five models we've found to be the most interesting, three are aimed at household customers (and possibly other smaller customers), one model is aimed at certain corporate customers and one last model is focused on large industrial customers. The aim has not been to develop completely new and untried models, but to learn from earlier studies and models already in use, and also to suggest adjustments to these models.

As far as is possible, the models are built on experience and have been shown to work and be accepted by the customers, and yield – or are expected to yield – good effects on the customer's load.

For the models aimed at household customers, two use the price as a control method, spot price and CPP respectively, while one model uses different types of direct load control. For the corporate customers we have chosen to focus on customers with access to emergency power and the possibility to aggregate this production/consumption reduction. For the large industrial customers the earlier work in Industribud is brought out.

4.2.1 Fixed price with the right to return

A model where the customers have the correct market price transferred to them in real time will yield the greatest potential gain. From a national economic point of view, a spot price model that continuously gives the correct price signals to the customers has a significant advantage. However, such a model exists, but is not very successful with household customers. The customers' choice of agreement shows that very few customers have chosen the closest current equivalent, i.e. spot price calculated on average monthly values (and settlement according to profiling). The greater majority of customers appear to choose an agreement with price fixing (1-year contract or longer). It warrants discussion whether it is reasonable to insure oneself against just this price

risk, while the household's other purchases don't have such options. The fact remains, however, that so far the customers have, to a large extent, chosen fixed price agreements.

In Norway, Trondheim Energiverk (TEV) has introduced a form of agreement called *fixed price with the right to return*. In this deal, the customer has a fixed price on an agreed volume while variations to this volume (up or down) are paid at spot price. In TEV's model, the spot price is deducted per month and it is therefore not applicable for the handling of the capacity problem, instead hourly deductions are required here.

Our suggestion is a model where the customer subscribes to a certain amount of electricity divided per hour. The degree of complexity in such an agreement can of course be varied, but we maintain that it is probably sufficient to vary the subscribed volume between seasons, alternatively months.

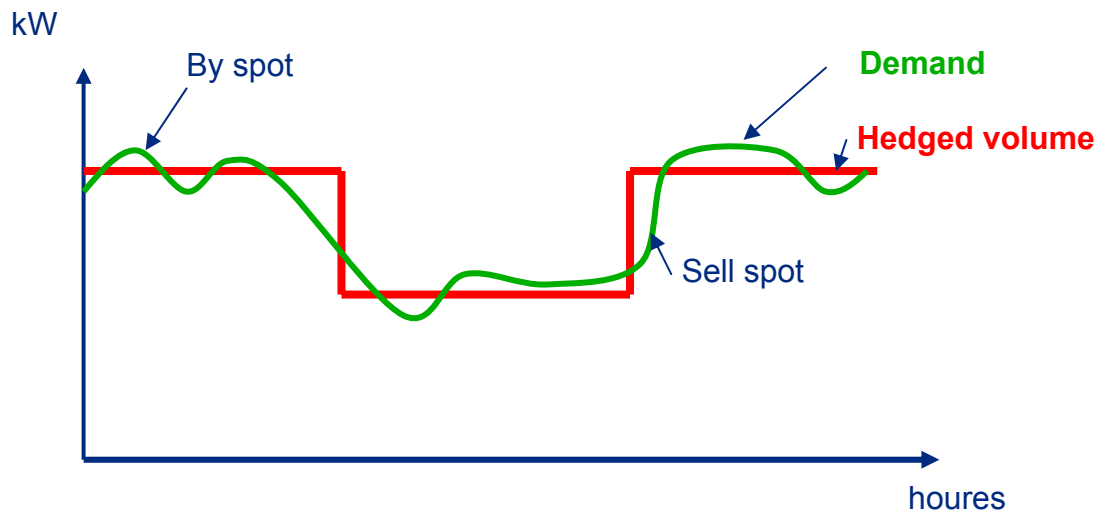


Figure 4.1 Fixed price with right of return.

Such an agreement means that the customer meets the spot price on the margin and therefore has the incentive to respond to the price signals, without it resulting in the whole price risk being shifted onto the customers. We view this as an attractive offer to the customers.

The advantage with a spot price contract, compared to the other models outlined in the report, is that gains can be achieved even in situations when no price peaks arise. The drawback is of course the continuous price information to the customer, making his decision more difficult. Instead of only reacting when a specific signal arrives, the customer needs to consider if any action is to be taken in each situation. For this reason there might be cause for some sort of signal enhancement in extreme situations, for example in the form of a text message warning of situations with unusually high price.

4.2.2 Dynamic time of use tariff (Critical Peak Pricing)

Critical peak pricing means that the customer has a fixed price on all his consumption, with the exception of a few hours that are defined as critical. On these occasions the price is set extra high to stimulate reductions in consumption. The customers are notified in advance that a certain period will be defined as critical, resulting in high prices and the customer can therefore take measures to reduce consumption during these time periods.

Critical peak pricing means you have a time of use tariff that is dependent on the current situation, which means the pricing model can be described as a dynamic time of use tariff, which is the terminology we will use from here on.

Dynamic time of use tariff has the advantage of giving a clear signal to customer when it is particularly important that they act. This can be expected to increase the response on these occasions and the model is easy for the customers to understand. The drawback with the dynamic time of use tariff is it doesn't give any price signals about the current availability and demand situation in instances that aren't defined as critical.

In Sweden, the model has been applied in trials within the frame of the Market Design project (see section 2.1). The results from the trials have been very promising. Approximately 20% of the customers (household customers) that were offered this tariff model have accepted it. These customers have halved their demand on average during the high price hours.

4.2.3 Direct remote control of small customers

In Sweden, there are around 300 000 family homes with direct electrical heating. Installing control equipment for electrical heating systems was investigated quite thoroughly during the late 1980's in Sydkraft's project Toppkap. The conclusion then was that this probably is cheaper than investing in peak generation. In Market Design, a system for soft control, still in operation, was tested. The system is functioning as expected. The customers have in general been willing to partake with only a small compensation. However, the costs for technology in the existing systems have been high.

The new metering (AMR and AMM) systems that now are been installed can probably manage this to a lower cost than was possible with the technology tested in the late 80's. Some of the grid companies plan to invest in systems prepared for some kind of two way communication, but we still don't know how many of the customers that will have readers with this kind of functionality.

4.2.4 Aggregation of emergency power plant

In connection with Svenska Kraftnät's extended purchase of reserve capacity, a new type of player has been established, the *aggregator*. The aggregator sells a solution in which existing emergency power plants are modified so they can be used as a capacity reserve. The total capacity from existing emergency power plants is estimated at 1000 MW (in total around 1600 MW). How much of it is practically available is less certain

and depends on the costs. Even without financing from SvK there is a role for these players. The business model is based on the aggregator signing a deal straight with the customer who purchases his electricity at spot price. Allowances for fixed costs can possibly be attained from the grid owner on the condition that these too can take advantage of the customer's flexibility.

It is probable that there are some advantages of scale in doing this and in particular those players who already have an operations centre are the ones with the best conditions to take upon this aggregator function. We have no set idea as to which player on the market would be the most suitable for this role, instead we see that electricity dealers, grid companies and other independent operators could potentially develop this business concept, as we've already seen examples of in Svenska Kraftnät's reserve capacity purchase. Our indicative cost estimate shows that profitability can be attained after only a few high price hours, given our assumption about the price during these hours.

4.2.5 Demand sell back

This method has been tried with large customers in the Industribud project and for middle-sized customers in Market design. The customer provides steady information to his electricity supplier where he states what compensation is required to reduce the consumption. If the spot price is higher than these bids, the electricity supplier can buy demand reduction instead of power.

4.3 Closing comments

The five models we have focused on here are in no way complete. They are, however, clear concepts that are relatively easy to carry out and have the potential to provide economic advantages to all involved: Customers, electricity suppliers and grid owners. While we maintain that the basic shaping of our suggestion is correct, we have not aimed at an overly detailed design. We hold that this is something that has to take shape in a collaboration that essentially involves the players in the electricity industry – but naturally in conjunction with the customers.

The various models involve various degrees of commitment from the customers, particularly in terms of what measures are taken to reduce the consumption. Direct load control means that the customer doesn't have to do anything, while models based initially on price control work by an active measure taken by the customer. Manual adjustment can lead to a risk of customers falling into a habit, and some of the flexibility is lost. The benefit of manual adjustment is, of course, that costs for technology are avoided.

The trials with dynamic time of use tariff within Market Design indicate that the price level during the high price hours are not of great importance, and that customers take more or less the same measures regardless of price during the notified hours. The gains from a spot price agreement in comparison to a dynamic time tariff could therefore be small. This said, there's nothing to suggest that the price models can't be combined with

various support systems for direct control of load based on price levels, which removes the problems associated with manual adjustment.

Perhaps it's time for electricity suppliers to introduce "Fixed price with the right to return" on a wider scale to smaller customers instead of today's "Take and Pay contract". That would reduce the electricity supplier's risks and open many new possibilities.

5 Analysis of regulations

The overall set of regulations in the electricity market (laws, stipulations, directives, agreements for balance responsibility etc.) do not appear to constitute any direct hindrance to the measures that can promote flexibility on the demand side and illustrated above. The business models mentioned can work with today's regulations. Some of the models have also been tested on the market.

When it comes to new possible business models for the grid companies in the shape of demand control and new services connected to the introduction of new automatic meter reading systems with the customers, the monopoly situation of the grid owners must be taken into consideration. This involves demand for reasonable prices and price supervision of these services. The introduction of demand control and new reading services from the grid companies also requires agreements between customer and electricity supplier as well as between grid owner and electricity supplier, besides agreements between the customer and the grid company.

An electricity supplier that is not responsible for balance might also need to re-regulate the conditions with the company that holds balance responsibility, taking into consideration the altered circumstances for supply.

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