Energimarknadsinspektionen
Swedish Energy Markets Inspectorate

Ei R2017:10

Measures to increase demand side flexibility in the Swedish electricity system

Abbreviated version

The Swedish Energy Markets Inspectorate (Ei) is a public agency with the mandate to work towards well-functioning energy markets.

The overarching purpose of our work is to ensure Sweden has well-functioning distribution and trade in electricity, district heating and natural gas. We shall also safeguard the interests of customers and strengthen their position on the markets.

In concrete terms, this means that we supervise the companies to ensure they comply with regulations. We are also responsible for developing fair play rules for the market and for informing customers of the rules that apply. We regulate the terms and conditions for the monopoly companies that operate the electricity and natural gas networks, and supervise the companies on the competitive energy markets.

Energy markets require rules to provide a level playing field
– we ensure that the rules are followed

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Foreword

Enabling more flexible demand is high on the European agenda. On the electricity market of the future, with a high proportion of renewable and variable electricity production, it will be important to utilise all the flexible resources in the electricity system, including flexible production, storage and demand side flexibility. In June 2015, the Swedish Energy Markets Inspectorate (Ei) were tasked by the Swedish Government to undertake a detailed study of demand side flexibility in the Swedish electricity system. The purpose of the task was to propose measures to facilitate and speed up the development towards greater efficiency on the electricity market through increased demand side flexibility.

The task was reported to the Government in December 2016 in the report *Åtgärder för ökad efterfrågeflexibilitet i det svenska elsystemet* (“*Measures to increase demand side flexibility in the Swedish electricity system*”) This report is an abbreviated version of the report, which has also been adapted for an international readership. This means, for example, that the more detailed descriptions of proposed legislation and administrative circumstances have been deleted, while some additions have been made in order to explain regulations and circumstances on the Swedish market that may be of international interest. Summaries of the views obtained from the actors on the market during the course of the work have also mainly been excluded from this abbreviated version.

The emphasis is on analysis of market conditions and the measures proposed within the areas *customers, electricity market, electricity grid* and *taxes and support systems*, as these areas are expected to be of most interest for an international readership. The detailed cost/benefit analysis presented in the original report has been retained, however, albeit only in a very summarised version.

The proposed measures are expected to lead to increased efficiency on the electricity market and to contribute to substantial societal benefit. We hope that it will be a source of inspiration for other countries, and serve as a basis for discussion on the development of the European electricity market in relevant forums.

Eskilstuna, May 2017

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Introduction

1.1 Background

On the electricity market of the future, with a higher proportion of variable electricity production in the form of wind and solar power, it will be important to utilise all the flexible resources in the electricity system, including flexible production, storage and demand side flexibility.

Flexible demand is desirable for many reasons. If demand is adjusted to available production, the risk of a power deficit reduces and thereby also the need for new investment in power stations and the electricity grid to safeguard demand during peak loads. Demand side flexibility can also contribute to less frequent activation of high-emission production resources in a deficit situation. Overall, increased demand side flexibility results in more efficient use of resources and contributes to the fulfilment of climate and energy policy goals.

Enabling more flexible demand is therefore a significant goal for the development of the Swedish electricity market, as well as for the European Union. Against this background, the Swedish Government has given Ei the following task:

> The Government tasks the Swedish Energy Markets Inspectorate to examine the prerequisites and obstacles that exist for different electricity customers when it comes to improving economic efficiency in the electricity market through increased demand side flexibility. The work shall include analysis of the incentives for various actors to increase demand side flexibility, in terms of both electricity trading and network tariffs. Based on this analysis, the Swedish Energy Markets Inspectorate shall propose measures that can facilitate and speed up the development towards greater efficiency in the electricity market.

The work has been carried out in a project team consisting of Karin Alvehag (project manager), Björn Klasman, Marielle Lahti, Elin Broström, Kristina Östman, Linda Werther Öhling, Göran Morén and Elon Strömbäck. The project principals were Therése Hindman Persson, Chief Financial Officer, and Tommy Johansson, Department Manager, Technical Analysis.

Actors on the electricity market were invited to give their views during the course of the work. While the report was in progress, market actors both proposed measures of their own for increasing demand side flexibility, and commented on the selection of measures presented by the project team.

1.2 Definition and delimitation

The concept of demand side flexibility can be defined in various ways. In this task, we have chosen the following definition:

> Demand side flexibility is a voluntary change in the demand for electricity from the grid during shorter or longer periods, caused by of some type of incentive.

This definition differs from other definitions of demand side flexibility, which start from a customer's electricity consumption instead of demand from the grid (see for example (CEER, 2014)). The reason why Ei has chosen a slightly different definition is that an electricity customer's electricity consumption does not have to be the same as the electricity demanded from the electricity grid if the customer has storage facilities or own production facilities. For this reason, we have instead chosen the wording *demand for electricity from the grid.*

In the report, only voluntary demand side flexibility is dealt with, that is when the customer has made an active choice. The analysis focuses on the financial incentives to electricity customers and from the actors that may stimulate, facilitate or buy customer flexibility. Flexible production and storage are not included, nor are net producers who produce more than they consume. On the other hand, micro-production and storage facilities at customers are included as parameters in the scenario analysis carried out in the task.

The task includes measures linked to both electricity trading and the electricity grid. When it comes to electricity trading, the focus is on the three markets for physical trading in electricity: the day-ahead market, the intra-day market and the balancing market. The financial market is not dealt with in the report. The task uses current market models as the starting point.

1.3 Execution of the task

The goal of Ei's task was to propose a package of measures to increase demand side flexibility in the Swedish electricity system. The <u>first step</u> of this work was to define obstacles to increased demand side flexibility and to draw up an action plan to remove these obstacles. In a <u>second qualitative step</u>, a large number of possible measures to increase demand side flexibility were identified within the areas *customers, market, electricity grid* and *taxes and support systems.* In a <u>third step</u>, the measures were combined into packages of measures, for which society's costs and benefits of increased demand side flexibility were quantified, to form the basis for the final proposal for a package of measures to increase demand side flexibility. This last step also included an analysis of customers' own financial incentives.

The analysis was carried out from a customer perspective. Several other actors do, however, serve as facilitators for achieving increased demand side flexibility. For example, there must be clear incentives for aggregators, energy service companies, network companies and electricity retailers for these to offer services and contracts that make it easy and profitable for customers to be flexible in their electricity use. Against this background, the following four types of obstacles to increased demand side flexibility have been identified:

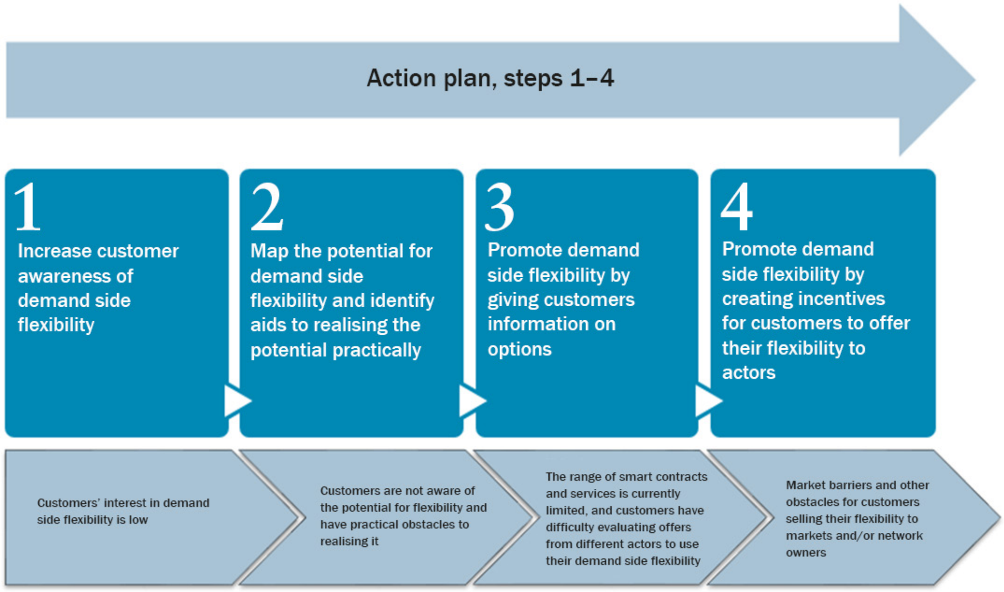
1 Customer interest in demand side flexibility is low.
2 Customers do not know about the potential of flexibility and lack the technical equipment that makes it easy for them to offer their flexibility.

3 There is currently a limited range of smart services and contracts for customers who wish to be flexible, and there is no tool for comparing and evaluating the offers that are available.

4 There are market barriers and other obstacles for customers selling their flexibility to markets and/or network owners.

The structure of the action plan and how it relates to these obstacles are illustrated in Figure 1.

Figure 1 Action plan for increased demand side flexibility in four steps, aimed at removing the various obstacles shown at the bottom of the figure



We have used an actor perspective when identifying the measures. Although electricity customers form the self-evident starting point for demand side flexibility, there are also other actors who can stimulate, facilitate or buy customer flexibility. They can be divided as follows:

- Electricity market actors, including electricity retailers, energy service companies and aggregators.
- Network companies, which can stimulate demand side flexibility through network tariffs, for example.
- Decision-makers, who design taxes or support systems that have a direct or indirect impact on the prerequisites for demand side flexibility.

To identify possible measures to increase demand side flexibility based on this actor perspective, we need to know which activities each actor can implement, which drivers and obstacles are linked to these activities, and what can be done to remove such obstacles and reinforce existing drivers.

Increased knowledge about customers' opportunities for and attitude towards being flexible in their electricity use constitutes important background information for answering these questions, and for this reason a number of supporting reports have been produced aimed at mapping the potential for demand side flexibility (Sweco, 2016), (Sten & Åström, 2016).

As a second qualitative step, the measures identified have initially been evaluated based on the fundamental principles presented in Table 1. In the qualitative analysis, Ei has also considered the opinions provided by the actors to Ei during the inquiry, as well as international experiences from similar measures.

Table 1. Fundamental principles for our proposed measures within the four areas: customers, electricity market, electricity grid and taxes and support systems

Customers	Electricity market	Electricity grid	Taxes and support systems
Demand side flexibility shall be based on voluntary customer choice	Actors causing costs to the system shall pay for these	Tariffs shall be objective and non-discriminatory	Actors causing costs to the system shall pay for these
Rules governing personal data protection for customers shall be complied with	Market-based solutions shall be used	Tariffs shall be compatible with efficient use of the electricity grid and efficient electricity production and electricity use.	Taxes and support systems can be motivating factors on immature markets with dissemination effects
It shall be easy for customers to be flexible	Market pricing shall be applied – the price shall reflect society's costs and the customers' valuation of the electricity production	Tariffs shall be designed by the network companies, not by the national regulatory authority	Taxes and support systems can be motivating factors if there are environmental or system effects that are not priced on the market
	The price shall reach the end consumer	Network companies may not carry out production or trading of electricity other than to cover their network losses and to reinstate operations following an outage	
Roles, responsibilities and rules shall be clear			
The measures shall primarily produce long-term effects			

In the third step of the process, where society's costs for and benefits from the measures were quantified, Ei chose to focus on the measures that we assess as particularly costly but crucial for getting demand side flexibility going. In accordance with the Swedish regulatory framework for Government tasks, a cost estimate was also done for the proposed measures requiring a change in legislation. The benefits were estimated based on four typical problems, where demand side flexibility is often mentioned as part of the solution: frequency regulation, power deficit situations, local network problems and inefficient resource use. The starting point for the analysis was that the measures are expected to be implemented over the period 2017 to 2025. To estimate the benefits, we started from the prerequisites on the electricity market in 2030, when the effect of the package of measures is expected to have increased demand side flexibility in Sweden.

2 Prerequisites for demand side flexibility

The Nordic and Swedish electricity systems, with their high proportion of hydro power, have comparatively good access to flexible production resources, which has historically meant that demand side flexibility has not been utilised to any considerable extent. Price volatility on the market has also been comparatively low, which has not resulted in any strong incentive for customers to be flexible in their electricity use either. On the other hand, there has long been a limited but stable price difference between day and night, and between weekends and weekdays. To some extent, the incentives for demand side flexibility have existed to even out this price difference, for example through the use of time-differentiated tariffs by some network companies. The most common type has been a higher tariff during daytime on weekdays for the winter half of the year, and a lower tariff during other times. Practical experiences of more active programmes for demand side control are few, however, and are mainly limited to pilot and demonstration projects.

Ambitious goals for an increasing share of renewable electricity production, development of micro-production and an increased proportion of electric cars will, however, mean that the need for flexible resources will increase in the future if we are to continue having a robust electricity supply. Interest in stimulating demand side flexibility in all parts of the electricity system must be seen in the light of this development.

2.1 Drivers and actors on a market for demand side flexibility

Like other parts of the European electricity market, Sweden has an "energy-only" market, where producers get paid for the electricity they deliver to customers, and not according to the capacity (power) they can supply. There is also a political consensus that there is no need to invest in a supplementary capacity market, in the way that is being done in several other countries within the EU. The only situation where producers can get paid for supplying capacity is within the strategic reserve ("effektreserven"), which is procured annually by Sweden's TSO, Svenska Kraftnät (see page 60).

The electricity market consists of various marketplaces that are "time windows" for physical trading in electricity: the day-ahead market, the intra-day market and the balancing market. In the Nordic countries, the vast majority of trading is done on the day-ahead market (spot market), and the "system price", which is the common Nordic price for all hours of the next following 24-hour period, is crucial for price formation within the other time windows (the intra-day and balancing markets and the financial market for long-term contracts). The intra-day market is primarily a correction market, where actors have the opportunity to trade into balance, including adjusting any earlier trading if the forecasts turn out to be wrong. The intra-day market closes one hour before the delivery hour. The balancing market is trading in automatic and manual reserves used by Svenska Kraftnät in order to maintain power balance during the hour of operation.

Nord Pool Spot[1] is responsible for the day-ahead market and the intra-day market, while Svenska Kraftnät is responsible for the balancing market. Owners of marketplaces play a key role in removing obstacles for demand side flexibility bids to enter the markets.

2.1.1 Electricity customers

For many customers, the economic drivers of demand side flexibility are central (NEPP, 2013). Household customers may have other drivers, however, such as feeling that they are assuming societal responsibility and contributing to environmental benefit by being flexible in their electricity use (S3C, 2014). Within the framework for this task, Ei has investigated customers' interest in and drivers for demand side flexibility.

Owners of a flexible resource (consumption as well as production) may receive income streams from the day-ahead market, the intra-day and balancing markets, and from the strategic reserve and their network company. Table 2 describes the factors that determine the market value of demand side flexibility.

Table 2. Factors that determine the market value of flexibility in various marketplaces

Marketplace/market actor	Factors that determine the market value of flexibility
Day-ahead market	Price volatility, i.e. price differences hour by hour. The absolute price level also impacts on the value of the flexibility.
Intra-day market	The price difference between the intra-day and the day-ahead market, plus the value of flexible resources that are not activated on the day-ahead market.
Balancing market	Remuneration on the regulating power market and the markets for automatic reserves.
Network companies	The structure of the network tariffs and remuneration for direct load control.
Strategic reserve	Remuneration with a fixed and a variable part for reserving production capacity or reduced consumption that can be activated in the event of an electricity deficit.

Source: Ei

Customers on the Swedish electricity market need to have a contract with their network company and a contract with an electricity retailer. Customers can freely choose their electricity retailer and electricity trading contract. On the other hand, customers cannot choose their network company, as the customer's geographic location determines which grid area the customer is connected to. Traditionally,

[1]To date, only Nord Pool has been appointed to operate the electricity marketplace in Sweden, but in January 2016 EPEX Spot also notified interest in establishing itself as an electricity market operator (NEMO) in Sweden.

electricity customers have only been consumers of electricity, but there are now customers who themselves produce electricity via solar cells, for example.

2.1.2 Other actors

There are a number of actors on the electricity market that can be part of driving development towards greater demand side flexibility.

The **system operator** needs flexible resources to balance the electricity system. In Sweden, the state-owned public utility Svenska Kraftnät is the TSO (Transmission System Operator) and is responsible for maintaining operational security in the Swedish electricity grid, as well as power balance in real time. In addition, Svenska Kraftnät has the task of procuring Sweden's strategic power reserve.

The **electricity retailer** plays a key role as the link between the customer and the day-ahead market, so that demand side flexibility can be factored into the bidding. Electricity retailers can offer contract formats such as hourly price contracts, which make it interesting for customers to respond to price signals from the market. Electricity retailers buy and sell electricity on the wholesale market in competition with other electricity retailers (currently 118 operating on the Swedish market). In addition to the purchase costs for the electricity, the price charged to customers includes balancing costs, price assurances, taxes and other surcharges. A large part of an electricity retailer's financial risk is the discrepancy between the amount of electricity purchased per hour and the amount the electricity retailer's customers consume per hour. Discrepancies between purchased volume and used volume create imbalance costs for the electricity retailer. The profit to the electricity retailer from demand side flexibility arises in the first instance from a reduced risk of imbalance costs through increased knowledge about the customers' flexibility.

The **balance-responsible party** also holds a key position. According to the Electricity Act, there shall always be a party with balance responsibility for each outtake and input point for electricity. This means that all electricity retailers (and producers) must have a contract with a balance-responsible party, or themselves be a party with balance responsibility. The companies with balance responsibility are electricity producers, major consumers or electricity trading companies that carry out the balance responsibility as a service to other actors without having their own production. Balance responsibility entails strict financial responsibility for imbalances. All information about customers' consumption must go via the balance-responsible party in order to allow it to make forecasts that are as accurate as possible, and in this way fulfil its balance responsibility.

The **network companies**' activities to stimulate flexible electricity use consist of both creating the prerequisites through metering, and also by utilising flexible resources for efficient network operation and network expansion through tariff design or through special contracts for load control, for example. Network companies refers to the approximately 174 distribution system operators (DSOs) that own the Swedish regional and local electricity networks. The regional networks transport electricity from the transmission grid to local networks, and sometimes to electricity customers with high power outtakes, such as industries. The local networks distribute electricity to all customers within their distribution area.

The **energy service companies** or **aggregators** will have new business opportunities and can offer new services to customers so that they can use and earn money from their potential for demand side flexibility. Energy service companies deliver services such as improving the energy efficiency of a customer's plant or premises. They may cover anything from simple energy advice to more complex contracts with guaranteed energy savings. An energy service company can also function as an aggregator. An aggregator combines the electricity usage or electricity production of several customers for sale, purchase or auctioning on organised energy markets.

Finally, **decision-makers** naturally impact the prerequisites for demand side flexibility, for example through the design of taxes and support systems. In Sweden, the energy tax constitutes a substantial proportion of customers' electricity cost. In addition, the Swedish electricity certificate system entails a surcharge on the electricity price. Sweden also offers investment support aimed at household customers for investments in solar cell production and energy storage. These taxes and support systems are described in more detail in Chapter 6.

2.2 Several types of demand side flexibility

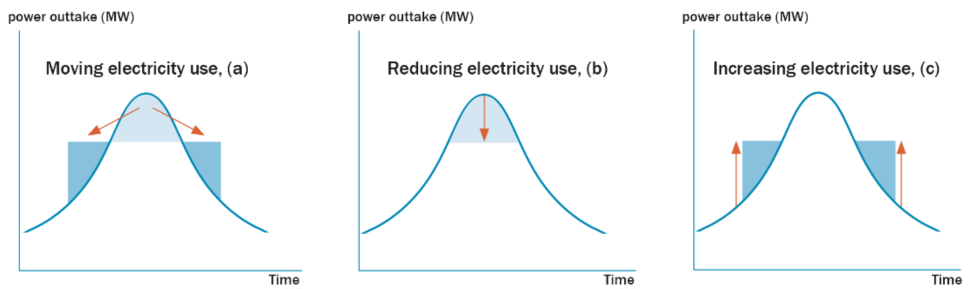
There are several types of demand side flexibility depending on the activities and needs of the customers. These types of demand side flexibility can be divided according to customers who:

a) move their electricity use to another time

b) reduce their electricity use

c) increase their electricity use

Figure 2. Several types of demand side flexibility



A customer who moves parts of the electricity use from high price hours to low price hours is illustrated in Figure 2(a). Typically, this relates to electricity use for heating, charging an electric car or using household appliances, for example, including activities that cannot be avoided, but can be carried out at another point in time.

A customer who can reduce the electricity need and does so temporarily during high price hours without needing to compensate for this later is illustrated in Figure 2(b). Typically, these are customers within electricity-intensive industry who choose to decrease production when the electricity price is too high.

Alternatively, household customers with electric heating who also use alternative types of heating.

A customer who can increase the demand for electricity during low price hours without reducing electricity use later is illustrated in Figure 2(c). Typically, these are customers who change their type of heating from one fuel to another.

A basic prerequisite for a well-functioning flexibility market is that the technical potential exists for demand side flexibility, and that it is *correctly priced* on the electricity market and by the network company. Further factors of importance for the prerequisites for demand side flexibility are

- Introduction of smart meters and hourly electricity metering
- Feedback of hourly values and metering data for controlling energy use
- Introduction of technology/solutions for flexible use and power reduction within property, housing and industry
- Introduction of electricity market-linked usage/automation/devices for energy flexibility at users and energy storage

In addition, clear information is important to enable customers to make well-informed decisions. The survey and interview study carried out on behalf of Ei shows that the various customer segments largely lack knowledge about demand side flexibility.

2.3 Current technical potential for demand side flexibility

Technical potential means the potential that a customer has, and that could be activated with the right incentive and technology. An example of technology that facilitates demand side flexibility is control equipment for load control. Load control entails that an actor, following agreement from the customer, remotely can control parts of the customer's electricity usage and optimise the electricity usage based on price signals from the market or the electricity network. Technology that controls electricity usage based on frequency deviations in the electricity system enables the customer to offer its heating loads as an automatic control resource in the frequency regulation.

Within the framework for this task, Ei has investigated how much knowledge there is about customers' potential and drivers for demand side flexibility. A summary of the estimated current technical potential for the various customer segments is presented in Table 3. The potential is dependent on underlying activities, which means that it varies considerably, both over a 24-hour period and over the year.

Table 3. Technical potential for demand side flexibility in various customer segments in Sweden

	Households	Properties	Service operations	Electricity-intensive industry	Other industry
Current technical potential for demand side flexibility (MW)	5500 – winter 3000 – spring 1500 – summer 4500 – autumn 2000 – average (water heating, direct-heating electricity and heat pumps) 300 (household electricity)	200 (ventilation)	70 (reserve devices)	1700 (power reduction or transfer to own electricity production within the forestry industry in particular)	300 (power reduction within industry, such as food, engineering and sawmills)
Source:	(Nyholm, et al., 2016), (NEPP, 2016), (Puranik, 2014).	(Cronholm, et al., 2006)	(Peter Svensson, AV Reserveffekt, 2016)	(NEPP, 2016)	(NEPP, 2016)

A large proportion of the technical potential exists among household customers in detached homes with electric heating. This potential is available during one to three hours (IVA, 2015). During this period, the control does not entail any noticeable reduction in comfort for the households, due to the heat inertia of buildings. During summer, when there is no need for heating, the potential for control within the household sector is considerably lower. The potential figures in Table 3 can be compared with the maximum power requirement in Sweden, which amounted to approximately 27 000 MW during the winter of 2015/2016.

The potential for demand side flexibility among industrial companies is very price-sensitive. When the electricity price causes variable production costs that are too high, price-sensitive industrial companies reduce their electricity usage from the network, usually by shutting down electricity-intensive production processes for a specified time, or by starting their own electricity production. It will probably only be possible to realise the full potential within the industrial sector a few times per year (IVA, 2015). Several actors within electricity-intensive industry are today active on the electricity market. They do this by participating on the regulating power market, selling their flexibility on the day-ahead market, and participating in the strategic reserve (Sweco, 2016).

In practice, one cannot count on the entire technical potential for demand side flexibility to be available at any one time. One reason for this is the effect of coincident peak load for a cluster of loads, which means that the resulting peak load from several customers is smaller than the algebraic sum of individual loads.

2.4 Scenarios for 2030

The need for demand side flexibility in the future is dependent on how the electricity system develops. Within the task, a number of future scenarios for 2030 have been produced with the help of the electricity market model Apollo, which models the majority of the European power systems.

The reference scenario in the analysis aligns with the energy policy agreement reached by a Parliament majority in June 2016. In addition, a number of alternative scenarios have been produced. The alternative scenarios have the same input data as the reference scenario, but nuclear power is assumed to have been decommissioned by 2030 and replaced by renewable electricity production. We also have a scenario where we assume a major integration of storage at customers' sites with their own solar power production. The scenarios are summarised in Table 4. Only changes in Sweden have been introduced into the alternative scenarios. Unchanged assumptions and prerequisites for the rest of Europe mean that the differences between the scenarios will always be fairly minor.

Table 4. Summary of reference scenario and alternative scenarios for Sweden 2030

Scenario	Consumption	Nuclear power production	Wind power production	Solar power production	Storage at customers' sites
Reference	142 TWh	50 TWh	39 TWh	0	0
Wind	142 TWh	0	50 TWh	0	0
Solar	142 TWh	0	39 TWh	11 TWh	0
Storage	142 TWh	0	39 TWh	11 TWh	287 MW

Source: Sweco and Ei

2.5 The need for demand side flexibility 2030

Customers' demand side flexibility can increase cost efficiency in the electricity system through:

- contributing to maintaining frequency in the electricity system (*typical problem 1, frequency regulation*)
- reducing the risk of power deficit (*typical problem 2, power deficit situation*)
- reducing price volatility and providing more efficient use of production resources on the electricity market (*typical problem 3, inefficient use of resources*)
- contributing to more efficient network usage that may reduce losses, costs for overlying networks and the need for investment into new capacity in the electricity network (*typical problem 4, local network problems*)

With an increased proportion of renewable variable electricity production in the electricity system, we may encounter increased challenges with *frequency regulation, power deficit situations, inefficient use of resources* and *local network problems.* The effects of our proposed measures are analysed based on how they can increase demand side flexibility and contribute to solving these challenges or the "typical problems".

2.5.1 Typical problem 1 – Frequency regulation

In Sweden, Svenska Kraftnät is responsible for ensuring the frequency does not diverge too much from the nominal value (50 Hz). Requirements placed on frequency reserves that are to contribute to frequency regulation concern how quickly they can be activated (activation time), how often they can contribute (repeatability) and for how long they can contribute (stamina).

With a higher proportion of variable electricity production in the electricity system, the balancing of production and consumption will be a greater challenge in 2020–2050 than it is today (NEPP, 2016). This applies both when low wind and solar power production coincide with high demand, and when high production coincides with low demand. Here, demand side flexibility can help to maintain frequency by reducing electricity consumption in deficit situations and increase electricity consumption in surplus situations (NEPP, 2016).

2.5.2 Typical problem 2 – Power deficit

When the demand for electricity is greater than the supply, we have a power deficit. Ahead of each winter, Svenska Kraftnät procures a strategic power reserve[2] that can be used to avoid a possible power deficit in extreme situations. Both electricity consumers and producers contribute to the strategic reserve by agreeing to reduce consumption or to reserve production. Power deficit situations are historically very unusual in Sweden, and the strategic reserve has only been activated on a handful of occasions during the last ten years.

The power requirement in Sweden is strongly temperature-dependent, and in 2014, for example, varied between approximately 8 500 MW in the summer and 25 000 MW in winter (NEPP, 2015). The risk of a power deficit situation in Sweden is greatest during very cold winter days. In systems with a large proportion of wind power production, it is however not given that a power deficit will arise only during peak load. Provided the price signals are correct, that is to say high during scarcity situations, demand side flexibility will help to balance the system even if the peak load does not necessarily reduce (NEPP, 2015).

No dramatic changes to the power requirement are predicted for the period 2030–2050 (IVA, 2016a). According to IVA, the power requirement is expected to change proportionally with the development of electricity use. Nor do the scenarios[3] produced by Ei show any major increase in demand. The demand will thus not be much greater by 2030, but with reduced supply of controllable production, there is a risk of a potential power deficit.

For the 2030 scenarios, we estimate the potential power deficit to 2 200 MW[4] for the reference scenario and 8 150 MW for the scenarios *Wind* and *Solar*, see Figure 3. The estimate of the potential power deficit is based on calculations of consumption during a really cold winter, which is estimated to occur every tenth year, a "10-year winter", and available production in Sweden. Consumption in 2030 for a 10-year winter is estimated at 28 400 MWh/h and is a projection of Svenska Kraftnät's forecast for 2016 (Svk, 2016). To estimate available production, the availability factors from Svenska Kraftnät have been used (Svk, 2016). The potential power deficit is the difference between available production and consumption, which can be balanced with the help of imports or demand side

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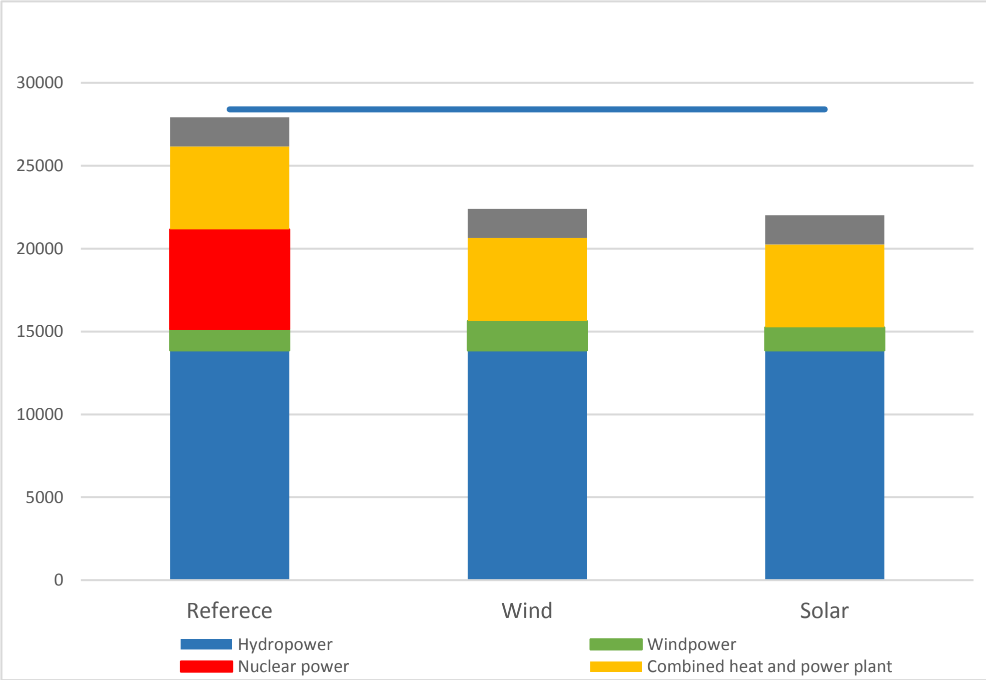
[2] Ordinance (SFS 2016:423) concerning Reserve Capacity and Act (SFS 2003:436) concerning Reserve Capacity.

[3] Ei's scenarios refer both to the scenarios developed within this task, and the scenarios produced for the Government mandate *Ökad andel variabel elproduction* (Ei R2016:14) ("Increased share of variable electricity production")

[4] The assumptions underlying these calculations are accounted for in the report *Ökad andel variabel elproduktion* (Ei R2016:14) ("Increased share of variable electricity production").

flexibility, depending on which flexibility resource is the most competitive. As solar power is not expected to be available, the potential power deficit is the same for the scenarios *Wind* and *Solar*.

Figure 3. Power balance (MW) for the scenarios *Reference*, *Wind* and *Solar* and consumption for a 10-year winter. The gap between consumption (line) and available production (bars) is the potential power deficit



Source: Ei and (Svk, 2016)

2.5.3 Typical problem 3 – Inefficient use of resources

From a socio-economic perspective, it would be desirable if flexible electricity customers cut down on their electricity use during scarcity situations with high prices and increase their consumption during low price periods, when there is a lot of renewable production in the system. A fundamental prerequisite for this is that customers who can be flexible are exposed to the price differences on the market, for example through hourly price contracts, and that the flexibility of these customers is factored into the price formation on the day-ahead market.

The price volatility on the spot market is a measurement of what the customer could save from bidding in his/her flexibility on the day-ahead market. Historically, the Nordic countries have had relatively low price volatility on the day-ahead market, compared with countries such as Germany and others which have a greater proportion of solar and wind power. The low price volatility in the Nordic countries is usually ascribed to our good access to flexible hydro power.

Household customers' interest in hourly price contracts, that is contracts with an electricity price based on the spot price hour by hour, has been limited. Up until spring 2014, only 8 600 of Sweden's total of 5.3 million customers had entered into hourly price contracts (Ei, 2014). However, it is more common for actors within electricity-intensive industry to bid in their flexibility on the day-ahead market.

Ei's scenario analysis for 2030 indicates that the annual average prices in all scenarios will double compared to the annual average price for 2015. This is primarily due to the expected price rises by 2030 for fuel and carbon dioxide. Price volatility is, however, expected to reduce slightly by 2030 compared to 2015[5]. Reduced price variations may seem surprising, as an increased proportion of non-controllable renewables production is usually expected to lead to increased price volatility. The reason is the European transmission grid, and how this is expected to be reinforced by 2030. Through trading with other countries, renewables production in particular will become less stochastic through effects of coincident peak load for a cluster of loads, and therefore possible to use more effectively. Where nuclear power is replaced by renewables production, price volatility will increase however, which can be observed by comparing the scenarios *Reference* and *Wind* in Table 5.

In the scenarios for 2030, we have simulated the effect of demand side flexibility being factored into the price formation on the day-ahead market. The demand side flexibility takes the form of household customers moving their electricity use for heating and industrial companies making a power reduction during high prices of 200 EUR per MWh according to the levels presented in Table 5. Demand side flexibility is expected to reduce price volatility when it is part of the price formation on the day-ahead market, and has the greatest dampening effect on price volatility in a scenario with a lot of wind power. The lowest price volatility is achieved in the scenario *Storage*, where customers' storage opportunities have a smoothing effect on the price curve.

Table 5. Absolute standard deviation as a measure of price volatility of the spot price for the various scenarios

	Without flex	With flex	Difference
Reference	19.0	17.6	-1.4
Wind	19.5	17.9	-1.6
Solar	18.6	17.4	-1.2
Storage	18.3	17.3	-1.0

Source: Ei

The scenarios for 2030 are based on an electricity system with good transfer connections, resulting in fewer high price hours in normal cases than there are low price hours. The price impact of demand side flexibility then works primarily through electricity heating customers moving their electricity use based on price variations between hours. This results in slightly higher average yearly prices, as the "troughs" of the price curve are filled more than the "peaks" are cut off, and that the number of hours with zero prices falls. In this way, producers with low marginal costs can benefit from bringing flexibility into the price formation.

2.5.4 Typical problem 4 – Local network problems

Local network problems entail the local electricity network having capacity limitations. Through flexible customers moving parts of their electricity use to

[5] The results show that the relative standard deviation falls from 0.44 to 0.4 from 2015 to 2030.

another time, costly investments in the network can be avoided or delayed. The network losses and costs to overlying networks also reduce in the electricity network when peaks are limited and the load is more even.

Within the framework for certain fundamental principles (non-discriminatory, cost-reflective, etc.), Swedish network companies decide for themselves how the network tariff shall be designed. Some network companies have introduced time-differentiated network tariffs for household customers, and studies have shown that customers respond to these price signals by moving parts of their electricity use to a time with a lower price (Bartusch & Alvehag, 2014).

The need to expand capacity in the networks will remain in the future as well, but if demand side flexibility is used, the networks can be used more efficiently. A high proportion of renewable electricity production and more electric cars will impact flows in the networks and may lead to capacity limitations being a bigger problem in the future. The number of local networks in Sweden that need to invest due to the charging of electric cars leading to an increase in peak load in winter may fall from 30 per cent to 15 per cent with demand side flexibility (NEPP, 2014a). This reduction in the number of electricity networks with investment needs is considered an effect of demand side flexibility from household customers and control of electric car charging.

Simulations carried out by IVA show that the electricity production of the future and the charging of electric cars will lead to greater variation in the power outtake by customers. In some cases, the energy flow may be reversed, including local networks transferring their production surplus to the overlying network instead of taking electricity from the overlying network. Increased integration of solar cells in local networks and wind power in local and regional networks will probably require capacity reinforcement at various levels in the electricity grid. If urbanisation continues in Sweden, with people moving increasingly to the major cities, the local networks in and around these cities may need to be reinforced (IVA, 2016b).

3 Measures within the customer area

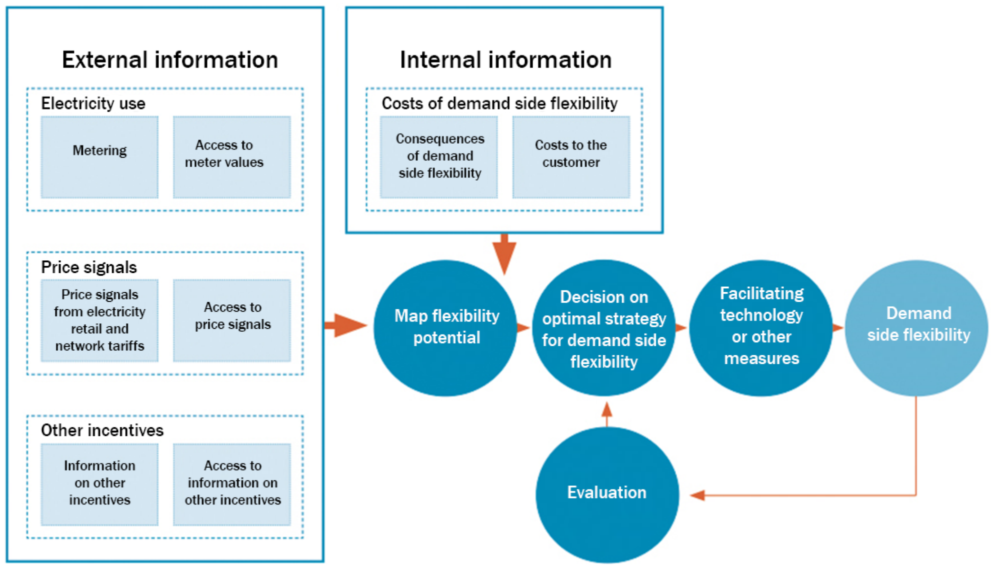
Ei has chosen to divide electricity customers into the customer segments household, property, service operations, electricity-intensive industry and other industry. This is because the need for information, the obstacles and the possible counter-measures differ between these customer segments.

3.1 Customers need information to enable them to make decisions on demand side flexibility.

To enable customers to make a well-informed decision on using their demand side flexibility, both *external* and *internal* information is required. Customers need external information from another actor, and this covers their own electricity usage including price data. Internal information relates to consequences from the customers' own actions, such as moving activities to another time. Customers may also have other drivers than financial ones, and therefore information about other types of incentives may also be relevant. Customers' decisions to use their demand side flexibility is illustrated in Figure 4.

Major industrial customers can often produce their own strategy for optimal demand side flexibility. For household customers and small to medium-sized companies, it may instead be a third party that helps the customer find an optimal strategy for demand side flexibility.

Figure 4. Customers' decision-making process for using their demand side flexibility requires both external and internal information



Source: (THEMA Consulting Group, 2014) and inhouse processing

The measures analysed in this chapter aim to encourage customers to make conscious decisions on using their potential for demand side flexibility and offering it to different markets.

A lot of the research into customer behaviour in electricity markets has focused on the potential for *increased energy efficiency* (Broberg, et al., 2014). This research is relevant also to demand side flexibility, as the technology that enables increased energy efficiency can in many cases also be used for demand side flexibility. Research findings in this area emphasise the importance of customers easily finding information and of actors, such as energy service companies, offering services that help customers to use available opportunities.

3.2 Regulation governing metering and customer information

3.2.1 Metering per hour

According to Swedish legislation, network companies are responsible for metering and reporting of customers' electricity consumption, and the way this metering is to be carried out is regulated in primary and secondary legislation. If the customer has a fuse contract exceeding 63 ampere, hourly metering shall be applied. Customers with a fuse contract of no more than 63 ampere may be metered by the hour or by the month. Hourly metering means that the customer's electricity consumption is measured per hour, while monthly metering means that the customer's consumption is measured per month.

Since 2012, network companies have been obliged to apply hourly metering without extra charge, if the customer's electricity contract so requires. This reform means that all customers have the opportunity to choose an electricity retail contract with a variable electricity price based on the applicable spot price per hour. If a customer does not have an electricity contract that requires hourly metering, but still wishes to have an hourly meter installed, the customer him-/herself must pay the extra cost. A change to this legislation is currently planned, however, meaning that all customers will be entitled to hourly measurement without extra cost.

On behalf of the Government, Ei has developed a proposal for functional requirements for smart electricity meters (Ei, 2015a), where the following requirements are of particular relevance for stimulating demand side flexibility:

- The network companies shall ensure that the customer gets continuous access free of charge to meter values and voltage values. The meter shall be equipped with an open, standardised interface and deliver near-real time values for power, meter reading, voltage and, as applicable, production. The customer shall have access to these values.

- The meter system shall register meter values at 60 minute intervals, and shall be possible to adjust to a 15 minute interval.

- It shall be possible to read all registered data remotely.

Ei also proposes that all meter systems should comply with the functional requirements by 2025. It is expected that the Parliament will process the proposal during 2017, and it will probably result in Ei and Swedac[6] together being tasked to produce proposals for the legislative changes that are required to regulate future functional requirements on electricity meters.

An exceptional case in terms of metering is collective metering, which means that a property owner has an overall agreement with a network company and an electricity retailer that also includes tenants' consumption. Collective metering is used in circumstances such as development of property-wide micro-production of renewable electricity. Collective metering is usually combined with subsidiary metering, so that customers can be charged for their actual consumption, but this is not a mandatory requirement.

3.2.2 Access to meter values for customers or third parties

Hourly metered customers are entitled to receive the hourly values from their network companies after the end of the delivery month, and no later than at invoicing, which shall be done at least quarterly[7]. The hourly metered customers discounted per 24-hour period may receive the hourly values in electronic format already within five working days after the metered 24-hour period[8]. An electricity retailer's charging shall be based on the customer's metered consumption. The invoice shall include information on the metered electricity use and the current electricity prices the invoice is based on. If the electricity retail agreement assumes that the amount of electricity transferred is measured per hour, the information may be made available via the electricity retailer's website, which the customer is informed of in the invoice[9].

The network companies shall provide information on historical consumption per day, week, month, and year without charge to customers with smart electricity meters. Customer who have an hourly price contract can also receive information about historical electricity use per hour, for example via personal login on the electricity retailer's website. Information about historical consumption shall refer to no less than latest three years, given that the company has had a contract with the customer for that period. Network companies are also obliged, at the customer's request, to report meter values to a company appointed by the electricity customer, such as an electricity service company.

Of importance in this context is also Sweden's decision to switch to an supplier centric model, and a central data management model (service hub). The supplier centric model shall simplify matters for the customer by making the electricity retailer (supplier) the customer's primary contact point. The service hub constitutes a platform for central management of the process of the network companies and electricity retailers, such as start-up of a plant, moving homes, changing electricity retailers and meter value management. As all actors have access to the same information in the central service hub, prerequisites are created for competition on

[6] Swedac is the national accreditation body for Sweden
[7] Chapter 6 Section 8 EIFS 2011:3 as amended by EIFS 2014:7
[8] Chapter 6 Section 5 EIFS 2011:3 as amended by EIFS 2014:7
[9] Chapter 8 Section 16 of the Electricity Act.

more equal terms between market actors, which makes it easier for new actors to enter the market. The supplier centric model will therefore make it easier for third parties to offer services.

3.3 Barriers that prevent customers from being flexible

Little interest in demand side flexibility among customers

The customer collective is generally not interested in their electricity use. For many households, electricity is an invisible product that they hardly notice, except during an outage. Demand side flexibility is also regarded as a complex area. Small electricity consumers in particular are more interested in increased energy efficiency as a way of protecting themselves from higher and more volatile electricity prices (Sweco, 2016). Within the categories property, service operations and industry, only one quarter of the customers are aware of the concept of demand side flexibility. The concept is better known among companies within electricity-intensive industry, which has historically been the sector supplying demand side flexibility in Sweden.

Customers' lack of knowledge about demand side flexibility prevents actors from entering the market. Contracts that enable demand side flexibility can also be perceived as more complicated than traditional electricity retail contracts, such as fixed price contracts and variable price contracts. Trust in the electricity market and its actors therefore plays a crucial role in customers daring to be flexible and wanting to enter into this type of contract. A study carried out at Nordic level also shows that the margins for both independent electricity retailers and electricity service companies are small, and that the cost of acquiring a customer is relatively high (VaasaETT, 2014). If customers perceive that it is good and important to review their electricity contracts and use their opportunities for flexibility, it will be easier for these actors to offer smart electricity contracts.

Customers are not aware of the potential of flexibility and encounter practical obstacles to realising it

Sweco's customer survey shows that few customers (3–6 per cent) within the customer segments electricity-intensive industry, other industry, property and service operations have investigated the opportunities of using their own flexibility potential. The customers feel that the greatest obstacles to flexible electricity use are the difficulties of calculating the operation-related costs that demand side flexibility entail, and difficulties of calculating the savings or income from demand side flexibility.

A mapping of customers' flexibility potential would remove these obstacles to some extent. The mapping can identify customers' technical potential for demand side flexibility, and thereafter an energy service company can estimate the benefits and costs of measures linked to demand side flexibility. Based on experiences from European pilot projects, S3C has produced a recommendation for how a third party can carry out a mapping of the potential for demand side flexibility together with small to medium-sized company customers[10]. Currently, there are no control measures to ensure customers get help in mapping their flexibility potential. On the other hand, there are control measures for mapping the potential for increased energy efficiency, such as requirements for energy declarations for property and for energy mapping of major companies.

Currently, the market for equipment to help customers optimise their energy use, such as load control equipment, is immature. This means that customers do not have many options when it comes to this type of equipment. There is also a lack of standards for equipment intended for monitoring and control in the home, which means that customers have less good prerequisites for combining equipment at a low cost. Standardising is being implemented at international level, however, and it is therefore difficult to indicate any measures for Sweden.

Research can contribute to understanding customers' drivers and prerequisites for demand side flexibility, to ensure any new services and business models are user-friendly and appealing to customers. Knowledge transfer from market and behavioural research and involvement of early adopters in the development and implementation phases are therefore success factors for realising the potential for demand side flexibility.

All customers do not have access to hourly values for their electricity use

Hourly metered measurements are a prerequisite for enabling actors to design attractive customer offers, where customers can benefit from their flexibility[11]. More than 90% of the electricity meters used in Sweden today are smart meters, which are enabled for hourly measurement, while still lacking some other functionality. They were installed in conjunction with Sweden introducing a requirement in 2009 for monthly readings of electricity consumption. Considering the normal working life of these meters, it will soon be time to replace them. With the proposed functional requirements, the floor for functionality in the Swedish meter population will then be raised.

If customers can see their consumption at the same time as it occurs, in real time, customers will have even better knowledge of their electricity use and how different activities in the home impact it. For this reason, it is proposed that the future functional requirements for electricity meters shall include a requirement for a standardised interface, from which real time data can be delivered[12].

A particular problem is the fact that many customers living in multi-occupancy buildings do not always have access to their meters, which may be located in a separate locked space. If developments show that access to the electricity meter is an obstacle for the development of the market for energy services, or for customers

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[10]http://www.smartgrid-engagement-toolkit.eu/fileadmin/s3ctoolkit/user/guidelines/guideline_introducing_demand_side_management_to_smes.pdf

[11] Or according to the shortest market time unit used – currently one hour – thus making hourly metering a prerequisite.

[12] The information received by the customer via the open interface is not quality-assured, and can thus differ from the information on which the charging is based.

taking action by themselves to reduce their electricity use, for example, there may be a need for new legislation to regulate access to electricity meters (Ei, 2015a).

Difficult for actors to gain access to hourly values

Historical meter data per hour is necessary for third parties to identify a customer's flexibility potential and design attractive customer offers, where the benefits and costs of demand side flexibility can be calculated for the specific customer. Despite the requirement that network companies shall make meter data available to third parties without extra charge, there are some difficulties. The network companies deliver meter data in various formats, which means that the third party companies must be able to receive the information on historical meter values in lots of different data formats, which may increase costs. After the introduction of the service hub, energy service companies will be able to receive hourly values from the hub, following the customer's agreement, and this will then no longer be an obstacle. The service hub may not be operational until 2020, however. The functional requirement for the electricity meter to have an open, standardised interface also entails improved opportunities to deliver services that are conditional on access to meter data in near-real time.

In addition to information on hourly values and real time data, information on the customer's flexibility potential would also help actors target their marketing of demand side flexibility services and design attractive offers to customers.

Difficult for customers to understand and compare offers

Transparent and easily accessible prices are a prerequisite for enabling the customer to form an opinion on the market value of demand side flexibility. Current hourly prices on the day-ahead market and the intra-day market are now available on the marketplace Nord Pool Spot, and several actors are showing these on their websites and via various applications to smartphones and other units. Electricity customers in Sweden can also compare electricity retail contracts relatively easily on one of the price comparison sites available on the Internet. All Swedish electricity retailers must continuously report fixed and variable price contracts to Ei, who presents this information on its own price comparison site Elpriskollen.

For network tariffs, network companies are obliged to clearly report their composition on customer invoices. It is thus possible for customers to receive complete information. However, customers may have difficulty relating the tariff to what they can do themselves to impact on costs. Some network companies offer their customers a choice between two different tariffs; time-based and non-time based. This is good for the customer, but there is currently no tool to help the customer to compare different network tariffs.

To enable an active choice, it is important to identify the overall savings potential when choosing both the electricity retail contract and the network tariff. Household customers and small to medium-sized companies in particular would benefit from such tools.

3.4 Proposed measures within the customer area

The proposed measures within the customer area are in line with the fundamental principles presented in Table 1. In addition, it is important that roles, responsibilities and rules are clear, and that the measures primarily provide long-term effects.

Table 6 shows a summary of proposed measures that can potentially contribute to increased demand side flexibility. Apart from these measures, the functional requirements for smart electricity meters relating to an open, standardised interface previously proposed by Ei are of particular importance for promoting demand side flexibility (Ei, 2015a).

Table 6. Activities, obstacles and measures to stimulate demand side flexibility from a customer perspective

Activities	Obstacles or lack of drivers	Measures
Create interested customers through customer-adapted information and efficient feedback	Lack of information on demand side flexibility for all customer segments	Customer-adapted information on demand side flexibility (information campaign and web portal) Need for ongoing information from electricity retailers to customers about demand side flexibility
Map the potential for demand side flexibility	Lack of information on the potential for demand side flexibility among property owners and companies	Include the flexibility potential in the energy declaration Inform on demand side flexibility ahead of the energy mapping of large companies Inform on demand side flexibility when supporting energy mapping of small and medium-sized companies
Access to meter data and information on the own flexibility potential	Some customers lack meter data per hour for their electricity use Difficult for actors to design demand services if meter data for electricity use per hour is lacking Actors lack information on the customer's flexibility potential	Hourly metering and access to hourly values for all customers[13] Voluntary reporting of flexibility potential to the service hub
Make it easy for customers to compare and evaluate offers	Difficult for customers to make a uniform comparison of offers for electricity retail and tariffs and understand the overall savings potential	Include hourly price contracts and network tariffs in Elpriskollen Develop Elpriskollen into a simulation tool, where customers can get information on the estimated saving of using their flexibility potential
	Difficult for other actors who want to develop comparison tools to get the information they need in a good format	Ei should facilitate access by other actors to data from sites such as Elpriskollen and information on tariffs

Source: Ei

[13]Design processes in the service hub that protect customer integrity and data protection are important for this measure.

Customer-adapted information on demand side flexibility and flexibility potential via various channels

Ei proposes a major **information campaign** targeted at various customer segments when the other parts of the package of measures proposed have been started. The purpose of the information campaign is to arouse the interest of customers and other actors in demand side flexibility. The information campaign should be carried out in collaboration with the actors that in some way come into contact with customers in relation to demand side flexibility, and whose information needs to be disseminated.

There is added value to be gained from a joint information campaign for both increased energy efficiency and demand side flexibility, as the customers' ability to impact their electricity costs will then be in focus. There are also many well-established channels for informing about energy efficiency that could be broadened to also include demand side flexibility. Ei's mandate already includes promoting demand side flexibility on the electricity market, but the proposed information campaign does not fit within the available framework and will require extra resources.

Ei also proposes the creation of **an independent information portal with topical information on demand side flexibility and energy efficiency** gathered together from several public authorities and other actors. The energy portal can then have links to more detailed information from other actors. Ei should be given coordinating responsibility together with the Swedish Energy Agency to develop such an energy portal. The information responsibility of the Energy Agency should include the opportunities available for companies within the demand side flexibility area, and be coordinated with activities relating to energy mapping of large companies and support to small and medium-sized companies in their work of making their energy use more efficient[14].

Examples of other actors who should contribute to the energy portal are the electricity network companies, the TSO Svenska Kraftnät and the National Board of Housing, Building and Planning. The National Board of Housing, Building and Planning should be responsible for information of what property owners can do within the areas of energy efficiency and demand side flexibility. Svenska Kraftnät should be responsible for information on how various flexibility resources can contribute to the strategic reserve and frequency regulation. There is already an information page from Svenska Kraftnät[15] with information on the prerequisites for demand side flexibility in the various markets, and this should be referenced by the energy portal. The network companies should be given additional responsibility for informing customers about how they can act to impact on their electricity network cost through tariffs and load-control.

Finally, electricity retailers should be given additional responsibility for **information on invoices** about the energy portal, plus information on the

[14] The support to small and medium-sized companies is financed via the European Regional Development Fund.

[15]http://www.svk.se/aktorsportalen/elmarknad/reserver/forbrukning-som-reservkraft/

customers' own flexibility potential where it has been reported to the service hub (further details on this measure later in the text).

Ei also proposes that the Government mandates the National Board of Housing, Building and Planning to review the opportunities of **including the demand side flexibility potential in the energy declaration**. The background to the Swedish legislation applicable to the energy declaration is primarily the Energy Performance of Buildings Directive (2010/31/EU) and the purpose is to promote efficient energy use and good indoor environment in buildings through a type of classification of the building. Since 2009, new buildings and buildings sold must have an energy declaration. The data relating to the flexibility potential that could be included in the energy declaration concerns areas such as type of heating, alternative heating sources, access to control equipment, own electricity production and access to storage.

According to the Act on Energy Mapping of Large Companies (SFS 2014:266, lagen om energikartläggning i stora företag), large companies shall carry out energy mappings at least every four years in order to find out how much energy is added to and used annually to operate the company. The energy mapping shall also give proposals for cost-effective measures that can be undertaken to reduce the energy use and increase energy efficiency. The information input to major electricity users that has already begun by the Swedish Energy Agency linked to energy mapping should be expanded to also cover information that measures to increase energy efficiency may include demand side flexibility, and how this can be done.

The Act covers approximately 1 400 companies, and just over half of Sweden's energy use. The energy mapping may be carried out by certified energy mappers, or through a certificated management system carried out by the company itself. Small and medium-sized companies are not covered by the Act, but may seek financial support to carry out an energy mapping. In order to qualify for the support, the Energy Agency places certain demands on what an energy mapping shall include, and how it is to be reported. It would be positive if such a mapping also included information on demand side flexibility, so that small and medium-sized companies also become aware of this potential.

Hourly metering and access to hourly values for all customers

The Council of Legislation's submission on *Functional Requirements for Electricity Meters* that is currently being prepared, proposes that all customers shall on request be given access to hourly metering without extra cost[16]. The proposal is proposed to come into force already in July 2017.

Ei makes the assessment that all customers, irrespective of the size of their fuse contract or type of electricity retail contract, need access to meter data with at least hourly values as a basis for enabling decisions on demand side flexibility. This assessment is justified, as a large part of the potential for demand side flexibility

[16]The proposal corresponds to the proposal made by the Swedish Coordination Council for Smart Grid Networks in the report *Planera för effekt!* (Plan for power!). SOU 2014:84.

exists in the segment single-family dwellings with electrical heating, which have a fuse contract for less than 63 ampere. Ei therefore proposes that hourly metering should be mandatory for all customers[17]. We propose that the measure is implemented through a change to the Electricity Act once the functional requirements for electricity meters have been implemented in secondary legislation.

For actors such as energy service companies and aggregators, historical meter data per hour is necessary information for enabling them to design attractive customer offers, where the benefits and costs of demand side flexibility can be estimated for the specific customer. Historical meter data per hour should therefore be stored in the service hub. Ei considers that at least three years of historical hourly values should be available to the customer or a third party at the customer's request, which is the number of years that currently applies for meter data on historical consumption in the metering regulations[18].

Voluntary reporting of flexibility potential to the service hub

To make the available flexibility visible to a third party, and to make it easier for customers to know the flexibility available, it might be advantageous to gather all information on the flexibility potential in a single place. As one of the prerequisites for this work has been voluntary flexibility, we propose voluntary reporting of the flexibility potential to the hub. The reporting may be done by the customer, either directly to the service hub, or via the electricity retailer, depending on the type of functionality the hub will have.

In order for a third party to find out that there is potential to offer flexibility services to the customer, the information needs to be available with reasonably easy access. The prerequisite is that the customer has given permission to the actor to view and access the information. In this way, customers can show when they are open to proposals from service companies, and when they no longer want help from an actor to find attractive offers.

Mapping the flexibility potential via the energy declaration and energy mapping should constitute good documentation for customers who wish to report their potential. Even if the reporting is proposed to be voluntary, it should be carried out according to a specific format, and the systems set up to receive data should be well-functioning and adapted to the needs of various actors. Proposals for formats and the data to be covered by the reporting to the service hub should be produced in collaboration between Ei, the National Board of Housing, Building and Planning, the Swedish Energy Agency and Svenska Kraftnät (as owners of the service hub).

Measures linked to Elpriskollen for promoting demand side flexibility

Ei has identified four measures impinging on Elpriskollen (Ei's price comparison tool) aimed at making it easy for customers to understand and compare offers. In 2015, Elpriskollen had around 63 500 visitors. It shall be possible for customers to

[17] Electricity customers in networks that do not require a concession, and who do not have their own electricity contract are not covered by this proposal.
[18] Chapter 11 Section 1 EIFS 2014:7

be linked on to Elpriskollen from the energy portal, if the customer wants help to compare various offers for network tariffs and electricity retail contracts. The number of visitors to Elpriskollen is therefore expected to increase.

I – Elpriskollen should also have information about available network tariffs

If the outcome is that network owners will increasingly be offering flexible network tariffs, it will become important for customers to get information on how the change of tariff impacts on the overall cost of electricity. One prerequisite for implementing the measure is that the corresponding reporting requirement to Elpriskollen is imposed on network owners as currently applies for electricity retailers. Our proposal is that the Electricity Act is supplemented with a provision that network companies shall also provide information on prices and terms to Ei, for the purpose of providing information to customers. In the longer term, it would however be more efficient if the information is available through the service hub, and that Ei gets the information from the service hub, to avoid double reporting.

As reporting of network tariffs may become an administrative burden if there are too many different versions of network tariffs, it would be efficient if this work was carried out after Ei has decided on regulations for how network tariffs shall be designed.

II – Elpriskollen's reporting requirement shall also include hourly price contracts

Household customers who wish to be flexible in their electricity use can currently not compare hourly price contracts using Elpriskollen. This is a major shortcoming. Hourly price contracts are an important prerequisite for certain types of flexibility, and it is therefore important that customers can compare different options in a good way.

It will be a challenge to find a way of presenting the cost of an hourly price contract to customers in an educational way, without "promising" the price stated. This problem exists even today for variable price contracts, however, so customers are already fairly used to relate to historical data as an indication of future price. Experiences from Norway can also be studied, where a corresponding price comparison tool[19] has been further developed, which also includes hourly price contracts in the comparisons.

III – Simulation tool in Elpriskollen

To enable customers to compare different alternatives offered by electricity services companies, it would be good if Elpriskollen could function as a simulation tool. In a simulation tool, customers download data from the service hub relating to historical consumption and the flexibility potential that exists (and that the customers have themselves reported in). This data can then be used to see how a new tariff or other offer of compensation for load control, for example, would impact on the customer's electricity cost based on the customer's consumption profile.

[19] Strømpris.no

As the service hub is not yet in place, it may take some time before this measure can be implemented. Discussions with Svenska Kraftnät on facilitating the implementation of producing a simulation tool have started, however.

IIII – Access for other actors to Ei's data to facilitate the development of smart services

Companies that wish to develop functions to make it easier for customers to compare contracts should be able to access the information reported to Ei via Elpriskollen and by other means. Access could be given through a specific interface or via manual handling to databases for which Ei are responsible. Some of the data reported by the electricity retailer is covered by confidentiality however, such as terms and conditions for contracts that will start applying at a future date, and should therefore not be made available.

No changes to regulations are necessary to enable Ei passing on information submitted. Some investment into development of the system for Elpriskollen will however be necessary. Over and above this, no major costs are foreseen for the measure, and the primary benefit is that more actors can interact with the customer and package good solutions.

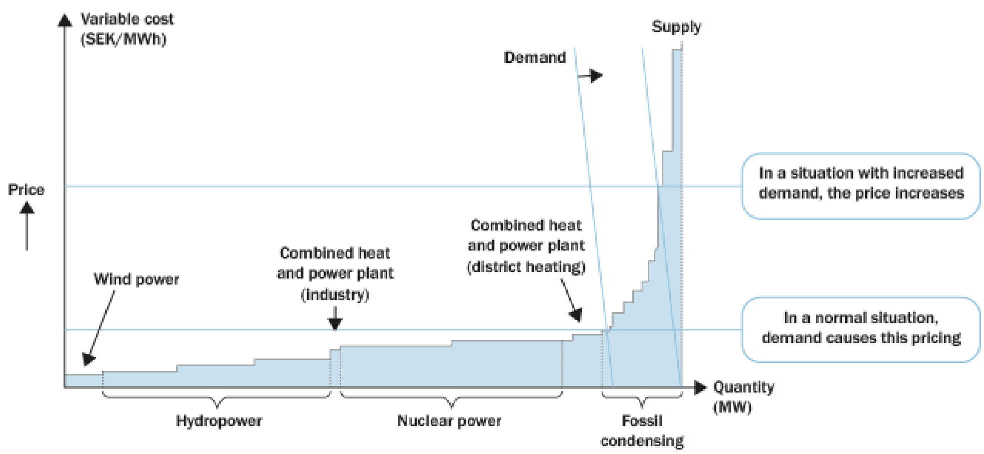
4 Measures within the electricity market sector

The wholesale market is the marketplace where electricity is traded between producers, retailers and major electricity customers. The wholesale market is a pan-Nordic, and increasingly pan-European, market, so it is therefore not possible to propose measures that entail detailed regulation at national level. Instead, it will be important to collaborate in the European work aimed at developing tomorrow's European wholesale market.

4.1 Demand side flexibility on the day-ahead market

Electricity is traded in several different marketplaces, and the day-ahead market refers to trade that occurs on the day before electricity delivery. In the Nordic countries, this trade is largely carried out in the Nord Pool electricity marketplace. Actors submit their buying and selling bids for the next day no later than 12 noon. The bids specify hour by hour how much the actor wishes to buy/sell, at what prices and in which electricity areas. In the next steps, when all the bids have been received, the marketplace summarises all bids in a supply and demand curve for each hour, and the price for each hour of the next 24-hour period, the spot price, is set where the curves for the selling bids and the buying bids cross each other (Figure 7). Marginal pricing is used in the day-ahead market, which means that all bids who get activated can trade at the established price, irrespective of their initial bids. No later than 13.00/1 p.m., the electricity marketplace publishes the prices for the next 24-hour period.

Figure 7. The price per hour is established where the curves for the selling bids and the buying bids (demand) on Nord Pool Spot cross each other.



If there are transmission limitations between electricity areas, the price differs between the various areas so as to reflect the supply and demand in each area.

Sweden is divided into four electricity area. If the transmission capacity is sufficient, the same price will apply for the entire market area.

Demand side flexibility as part of price formation (proactive demand side flexibility)

Demand side flexibility on the day-ahead market can be divided into proactive and reactive demand side flexibility. Proactive demand side flexibility enters into price formation by the balance responsible party having some form of control or safe knowledge about its customers' actions, for example that they reduce the heat load if the price rises above a certain level, and that the balance responsible party can make bids adjusted for this. With increased proactive demand side flexibility on the day-ahead market, peak loads are reduced, which in turn leads to reduced price differences between peak load and low load hours. In this way, more efficient use of production resources, reduced risk of power deficits and more benefits for the network companies are achieved.

Reactive demand side flexibility means that customers react once the prices on the day-ahead market have become known. If the customers' reactions cannot be predicted by the balance responsible party, this leads to increased imbalance costs for companies with balance responsibility and for Svenska Kraftnät (Ei, 2016b; Fritz, et al., 2013; Sweco, 2011). Studies have shown that reactive demand side flexibility, where 700 000 households react to the price when it has already been set, can have a significant impact (Fritz, et al., 2013) on the intra-day and balancing markets, resulting in increased costs for imbalances. The result indicates that comprehensive reactive demand side flexibility will lead to major challenges for balance responsible parties.

Proactive demand side flexibility is therefore to be preferred to reactive demand side flexibility. Promoting demand side flexibility on the day-ahead market therefore requires products designed to utilise the specific characteristics of demand side flexibility.

Hourly price contracts and settlement

To enable customers to adjust their electricity use according to hourly variations in the electricity price, the price signal needs to reach the customer, for example via an **hourly price contract**. An hourly price contract means that customers are charged for the actual consumption per hour, instead of according to a standardised consumption profile. With an hourly price contract, there is a real opportunity and incentive for customers to control their consumption so that more electricity is used when the price is low, and less electricity when the price is high.

The design of the **settlement** process also impacts the prerequisites for demand side flexibility. Settlement is the process where the energy volumes of the balance responsible party are set, quality-assured and priced, and thereafter form the basis for charging. The network companies are responsible for setting and reporting quality-assured energy volumes to Svenska Kraftnät, who manage pricing vis-a-vis the balance responsible parties. The balance responsible parties then charge electricity retailers, who in turn charge the customers.

By means of an exemption in current legislation, network companies can choose to apply monthly settlement, or settlement based on profiled consumption, instead of settlements per 24-hour period for their hourly metered customers with a connection contract no higher than 63 A. The exemption was justified by the costs that two separate settlement systems might entail for some network companies. The option of settlement based on profiled consumption has been criticised by electricity retailers and balance responsible parties, as it is thought to entail a risk of higher imbalance costs for hourly metered customers. Balance responsible parties must trade into balance according to the network area's preliminary standard consumption profile, despite retail customers being charged per hour. The electricity retailer therefore has no incentive to offer customers contracts that encourage a consumption change based on the spot price.

To increase the incentive for electricity retailers to offer hourly price contracts, Ei has proposed to the Government[20] in an interim report that the option for settlement based on profiled consumption shall be abolished. Even if customers with hourly price contracts are not impacted financially by the settlement method used, hourly settlement per 24-hour period may be preferable. Customers can they get quicker feedback on their electricity use, which might make it more attractive to choose an hourly price contract and other flexibility services.

Bid format

To optimise flows between electricity areas and therefore make the use of infrastructure and production plants more efficient, market coupling for the day-ahead market in north-west Europe was launched on 4 February 2014. The market coupling is achieved via an algorithm known as Euphemia[21], which was developed in collaboration between electricity marketplaces and system operators.

When the network code for capacity allocation and congestion management (CACM[22]) is introduced, each member state or national regulatory authority in each member state shall appoint at least one nominated electricity market operator (NEMO). To date, only Nord Pool has been appointed NEMO for Sweden, but in January 2016 EPEX Spot also notified interest in establishing itself as NEMO in Sweden. The regulations for electricity marketplaces mean that individual marketplaces no longer have the option of developing their own products/bid types.

The minimum bid volume on the day-ahead market is 0.1 MW, and the following ways of bidding in proactive demand side flexibility currently exist:

- *Simple hourly bids* entail a bid curve where the volumes desired to be bought or sold can vary in price, and in this way take account of the price sensitivity of the demand.

[20] Slopad schablonavräkning för timmätta kunder? (Abolish standard offsetting for hourly metered customers?) (Ei R2016:03)
[21] Pan-European Hybrid Electricity Market Integration Algorithm.
[22] Capacity Allocation and Congestion Management

- *Flexible hourly bids* value the flexibility by reducing the desired volume during the most expensive hour/s. Here, the volume, desired price and the duration in hours can be stated, but not exactly when the period falls during the 24-hour period.

- *Block bids* are bids based on longer time intervals – three hours or longer – if the weighted average price for these hours is higher than the stated price level. Block bids are more common on the production side.

- *Exclusive groups* are a type of block bid where the bid producing the greatest societal benefit is given precedence.

Björndalen and Jörnsten propose that a dynamic bid format that allows a specific volume to be delivered over a number of hours, with minimum and maximum volumes stated per hour, where the overall cost is optimised, is to be preferred in terms of demand side flexibility. A prerequisite for the dynamic bid format is equipment that can automate the bids and corresponding control of the devices that will contribute with the flexibility (Björndalen & Jörnsten, 2014).

In CACM and the guidelines for forward capacity allocation (FCA), a common process for product design, maximum and minimum prices on the day-ahead market and on the intra-day market have been determined. As the decision on product range is taken at a specific time and is then valid for a long time ahead, it is important that the decision is forward-looking and adapted to future challenges. Ei considers it an advantage that the national regulatory authorities can be part of impacting the product range and therefore intends to play an active role in this area.

Opportunities for and obstacles to increased demand side flexibility on the day-ahead market

The most important prerequisites for proactive demand side flexibility are that the price signal reaches the electricity customer, for example by the end consumers having an hourly price contract, and that the bid format enables demand side flexibility to be bid into the day-ahead market. Over and above this, obstacles in the form of costs and access to price information have been identified.

Hourly price contracts and settlement

Ei's work on following up the hourly metering reform (Ei, 2014) established that 68 per cent of the electricity retailers offered hourly price contracts based on hourly metering. Of these, 21 per cent chose to only publish prices and information on their websites, while a further 6 per cent showed prices on the website and marketed the contracts actively via various sales activities. Approximately one third of the electricity retailers did not market their hourly price contracts actively, which meant that electricity customers had to contact customer services to obtain information on hourly price contracts. The fact that only a small proportion of customers have chosen hourly price contracts is therefore not particularly surprising.

One reason why hourly price contracts have not been marketed particularly actively by many electricity retailers is that the simplified settlement rules based on profiled consumption have created a risk for electricity retailers and balance responsible parties. To reinforce the electricity retailer's incentive to offer customers contracts that encourage a change in consumption based on the spot price, Ei has, as previously mentioned, already proposed that the simplified settlement rules should be abolished.

Forecasts and bidding formats

Good bidding formats for demand side flexibility enable electricity retailers to agree with their customers to use the customers' flexibility in their bidding on the day-ahead market. The balance responsible party and electricity retailer will then know whether the customers are using their flexibility resources or not, which reduces the risk for forecasting errors. None of the bidding formats available on the day-ahead market in the Nordic countries today can be used to move loads between times at a reasonable level of risk, as there is no option of linking bids. Elforsk has stated that it a fundamental problem on the day-ahead market is that the bidding formats are designed to match the flexibility opportunities of production plants (Björndalen & Jörnsten, 2014). The market is not adapted for actors who wish to place bids based on the flexibility characteristics of pumped storage power plants, energy storage plants or other technologies that enable load shifting.

Turnover fee to the electricity marketplace

Trading on Nord Pool Spot is charged with a turnover fee. Actors with both production and consumption in the same country can use gross bidding, which means that these actors do not have to offset their selling and buying volumes internally for cost reasons, but can offer all of their gross production and buy their gross consumption on Nord Pool Spot. It has been commented that this gross bidding entails a competitive advantage for an actor with both production and consumption. However, as the turnover fee contributes to increasing liquidity on the day-ahead market, we have chosen not to continue with measures that would mean the fee changed.

4.2 Demand side flexibility on the intra-day market

An alternative, or complement, to flexibility on the day-ahead market is for electricity customers (or aggregators who aggregate the consumption of several electricity customers) to offer their flexibility on the intra-day market. The intra-day market is used primarily by balance responsible parties, even if there is no requirement to be a balance responsible party in order to participate.

Trading on the intra-day market[23] opens at 14.00 on the day before and closes one hour before the delivery hour. Trading is carried out continuously over this period – bids are matched as soon as a counterparty is found, which means that the trading takes place between two parties and without any price impact on other transactions. Trading on the intra-day market is associated with fees. The bid types available on the intra-day market differ slightly from the bid types on the day-ahead market, however.

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[23] Nord Pool Spot's intra-day market is designated Elbas

The intra-day market is primarily a correction market, where actors have the opportunity to trade into balance, including adjusting any earlier trading if the forecasts turn out to be wrong. For example, the temperature may differ from that forecast, which impacts on heating requirements and therefore consumption. The volumes on the intra-day market are relatively small (4.9 TWh/year) compared to the day-ahead market (361 TWh/year), but this might change. On other European markets, the intra-day market plays a greater role than in the Nordic countries, as many actors conduct a greater part of their trading there.

The measures we propose for the day-ahead market, and partly also for the balancing market, may also promote demand side flexibility on the intra-day market. But we are not proposing any specific measures for the intra-day market.

4.3 Demand side flexibility on the balancing market

The balancing market consists of automatic reserves that correct minor frequency divergences, and manual reserves that are used for larger frequency divergences. The manual reserves are traded on the regulating power market, which is a common Nordic market. The Nordic transmission system operators are also working on creating a common market for automatic reserves. There is also work in progress to enable joint balance settlement in the Nordic countries, as a stage towards a common retail market. There is a strong link also on the balancing market to the European work with the Network Directive and the revised Electricity Market Directive[24].

The balancing market – automatic reserves

The automatic reserves FCR[25] and aFRR[26] are frequency-regulating reserves that are activated automatically, as soon as the frequency diverges from 50 Hz. The automatic reserves may be a power product that provides compensation for being available for activation, or an energy and power product that also provides compensation for energy on activation.

For FCR, the minimum permitted bid size is relatively small, 0.1 MW. The balance responsible party is paid according to the bid price stated with the bid (*pay-as-bid*). To participate on the FCR market, a provider has to pass a pre-qualification test in collaboration with Svenska Kraftnät.

The product aFRR was introduced to the Nordic system in 2013 to improve frequency quality. The Nordic system responsible parties for transmission systems have agreed to introduce a common Nordic capacity market for aFRR as from 2018. Just like on today's Swedish aFRR market, bids shall be given in steps of 5 MW and be compensated for using *pay-as-bid.* As from the second half of 2018, the Nordic

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[24] COM (2016) 864
[25] Frequency Containment Reserves
[26] Automatic Frequency Restoration Reserves

market shall include activation based on lowest energy price, instead of activation based on the bids contracted two days in advance.

Table 7 summarises the requirements that demand side flexibility must fulfil to be part of the procurement process for the two products FCR and aFRR[27]. FCR is here divided up into FCR-Normal and FCR-Disturbance.

Table 7. Requirements that demand side flexibility must fulfil to be part of the procurement process for the two products FCR and aFRR

Product for automatic reserves	Bid size and pricing	Activation time	Other requirements	Volume requirement and time window for trading
FCR-Normal (Power and energy product)	Minimum 0.1 MW Power compensation according to pay-as-bid Energy compensation according to upwards and downwards regulation price	63% within 60 s and 100% within 3 min	Pre-qualification is required and real-time metering is a requirement. The product shall manage both upwards and downwards regulation.	Approx. 200 MW for Sweden. Capacity is procured 2 days and 1 day before the delivery hour.
FCR-Disturbance (Power product)	Minimum 0.1 MW Power compensation according to pay-as-bid	Activation time 50% within 5 s and 100% within 30 s.	Pre-qualification is required and real-time metering is a requirement. The product shall manage both upwards and downwards regulation.	Approx. 400 MW for Sweden. Capacity is procured 2 days and 1 day before the delivery hour.
aFRR (Power and energy product)	5 MW Energy compensation according to upwards and downwards regulation price	Full activation 120 s.	Pre-qualification is required, where IT infrastructure for activation and follow-up is a prerequisite. Regulation only in one direction. Activation during peak load hours. Shall be able to remain activated for one hour.	Approx. 100 MW for Sweden. Procured once a week for the following week's working days.

Source: SvK[28]

Opportunities and obstacles for demand side flexibility to participate as an automatic reserve

To replace regulation volume from the production side with regulation volume from the demand side, it must be ensured that demand side flexibility is always available. For this reason, electricity use offered as an automatic reserve must be electricity use that a customer can refrain from using temporarily, such as devices for cooling and heating. The customer could then enter into a contract with an actor who is allowed to direct the load within a temperature interval accepted by the customer in advance.

[27] The table describes the current requirements for aFRR, which differ slightly compared to the planned common Nordic aFRR market, which will start in 2018. The requirements for bid size and for capacity to be compensated for using pay-as-bid will however remain in 2018.

[28] http://www.svk.se/aktorsportalen/elmarknad/reserver/forbrukning-som-reservkraft/
http://www.svk.se/siteassets/aktorsportalen/elmarknad/reserver/handel-och-prissattning_ny.pdf

Although demand side flexibility does not currently participate in FCR or aFRR procurement, Svenska Kraftnät states that **an increasing number of actors are interested in being flexible** (Thell, 2016). Svenska Kraftnät is planning to start a pilot project in December 2016, where the hot water heaters of 100 household customers are aggregated in order to contribute with the product FCR-N for two months. The aggregated consumption will be controlled centrally by installing control and metering equipment on all units. The aim of the pilot project is primarily to get input into the strategy developed by Svenska Kraftnät to enable demand side flexibility as a resource for frequency maintenance, and to evaluate whether demand side flexibility resources can fulfil the requirements for primary regulation (Thell, 2016).

The prerequisites for competition on the automatic reserve market are limited. Currently, hydro power provides the automatic reserves, and Svenska Kraftnät has developed a specific instruction for how the reserves are to be priced [29]. The fact that the market is designed so specifically for hydro power makes it difficult for the owners of other resources to enter this market. With better prerequisites for competition, the need for an instruction for how the bids may be priced could be reduced, and it may be suitable to **switch from pay-as-bid to marginal pricing**.

Marginal pricing would also provide a greater incentive for aggregators to **invest in communication systems for control**, for example. Svenska Kraftnät emphasises that frequency regulation via demand side flexibility, where several smaller resources are aggregated, requires investments in administration and communication systems.

Currently, the price for activated bids at aggregated level are published on a website that is primarily intended for those who are already familiar with the bidding. **Increased transparency in terms of prices** is needed to make it easier for all potential actors to assess the profitability of investing in products and infrastructure that enables participation in the markets for FCR and aFRR.

The fact that the minimum **bid size** for FCR is relatively small, 0.1 MW, is advantageous to demand side flexibility. For aFRR, however, bids must be made in steps of 5 MW, which is an obstacle for plant owners with plants that can deliver aFRR, but not in volumes as large as 5 MW.

Balancing market – regulating power market

The market for manual reserves is the Nordic regulating power market. Voluntary bids for upwards and downwards regulation are made to the regulating power market, starting 14 days before the start of the delivery day, and up to 45 minutes before the delivery hour. Today, the bids on the regulating power market consist primarily of bids from production resources, but Svenska Kraftnät states that there are also bids from consumption on the regulating power market. For most hours,

[29] The rules for contributing with FCR is described in Svenska Kraftnät's balance responsibility contract: http://www.svk.se/siteassets/aktorsportalen/elmarknad/balansansvar/dokument/balansansvarsavtal/7-regler-for-prisberakning-av-budpris-for-fcr.pdf

these relate to 10–20 MW consumption bids. The consumption bids are often priced higher than the production bids, and are therefore very rarely activated.

The regulating power market uses marginal pricing, which means that all activated upwards regulation bids are priced the same as the most expensive activated bid. Sometimes, exceptions have to be made due to transmission limitations or the time required before the resource is fully activated. Divergences from the principle of "lowest bid first" are called special regulation. Only balance responsible parties may make bids; this applies to both production bids and bids for consumption reduction.

Apart from volume (MW) and price (SEK/MWh or EUR/MWh), the bids shall include information about geographic location and how quickly an activatebid can be fully activated. Bids must therefore be made per regulation object. The minimum bid volume per hour is 10 MW in all electricity areas, apart from SE4, where the requirement for minimum bid is 5 MW.

Regulation objects whose activation time is 15 minutes or less must be able to send meter values in real time. For regulation objects requiring a longer time before being fully activated, real time metering is voluntary to date. It must be possible to maintain the consumption reduction throughout the delivery hour in question, and to adjust it within 15 minutes. Currently, consumption reductions are activated primarily during daytime during transmission limitations between production surpluses in the north and production shortages in the south, as it is otherwise possible to access cheaper resources. The maximum permitted price for upwards regulation bids is 5 000 EUR/MWh. Regulating power prices are not available in real time, but are published by Nord Pool Spot within an hour of the end of the operating hour, after having been notified of the current price by the Nordic system responsible parties. Table 8 summarises the requirements that demand side flexibility must fulfil to be bid into the regulating power market.

Table 8. Requirements that demand side flexibility must fulfil to be bid into the regulating power market

Product for manual reserves (Regulating power market)	Bid size and pricing	Activation time	Other requirements	Time window for trading
mFRR (Energy product)	Min 10 MW (5 MW in SE4) Marginal price of activated upwards and downwards regulation price	Within 15 minutes	Longer activation time is permitted Real time metering is required in part	Energy bids are made no earlier than 14 days before the delivery hour, with adjustment no later than 45 minutes before the delivery hour The bids shall include price, volume, regulation direction, activation time and regulation object

Source: SvK[30]

[30] http://www.svk.se/aktorsportalen/elmarknad/reserver/forbrukning-som-reservkraft/
http://www.svk.se/siteassets/aktorsportalen/elmarknad/reserver/handel-och-prissattning_ny.pdf

Opportunities and obstacles for increased demand side flexibility on the regulating power market

The balancing market is a good alternative for the actors that can fulfil the requirements for minimum bid size, communication format, availability and real-time metering. These requirements apply for all Nordic system responsible parties, and the requirements are also shown in future network regulations and commission guidelines. The financial compensation is often higher on the regulating power market than on the day-ahead market, for example.

There is a requirement to access the entire volume via one telephone call, as the activations are still made by telephone. Strict requirements for minimum bid size makes aggregation necessary, and if the bids fall short of the minimum permitted size, they must be aggregated within an electricity area, as there is also a requirement for geographic location.

System responsible parties have a driver to develop the regulating power market, as it important to receive sufficient bids for all future operational situations. In 2013, the system responsible parties in the Nordic countries (E-Bridge, 2013) agreed of four measures, which were considered efficient and possible to implement within a few years:

- A reduction of the minimum bid size to 1 MW for the entire Nordic area
- Introduction of electronic activation, which are a prerequisite for reducing the minimum bid size to 1 MW
- Harmonisation of the minimum activation time for a bid to be price-setting
- Introduction of an option to mark a bid with a "resting period", which would facilitate demand side flexibility bidding

A special issue arises when network owners feed-in and outtake contracts are not sufficient to permit any regulating power bid. This is, however, addressed in Svenska Kraftnät's user contract, as *a fee for exceeding a contract does not have to be paid if the excess is due to redistribution arising due to faults or operational rearrangements of the transmission network or in the event of an accepted regulating power bid.* As a consequence of this, it is no longer a regulatory obstacle, but on the other hand it may constitute an obstacle if the information does not reach the balance responsible parties. The balance responsible party assumes that it must stay within the framework also in terms of regulating power bids, and avoids placing regulating power bids when the limits for the feed-in and outtake contract risk being exceeded.

4.4 The aggregator's role within demand side flexibility

An aggregator can enter into contracts with a number of electricity customers to aggregate their demand side flexibility[31] into larger volumes and make bids in several marketplaces for electricity trading or to network owners or system

[31] Aggregation may also include minor producers. For example, the electricity customers whose consumption is aggregated by the aggregator may have their own small-scale production.

operators. The EU Commission's proposal for a review of the Electricity Market Directive[32] and the Electricity Market Regulation[33] includes proposed legislation aimed at reinforcing the aggregator's role. The EU Commission's legislation proposal was preceded by discussion at European level on what aggregator model should be implemented in Europe to promote demand side flexibility.

Aggregators can stimulate increased demand side flexibility by helping to overcome some of the obstacles the current market rules may entail, such as requirements for minimum bid size, communications and fees. An aggregator may have established methods, communication systems, investments in infrastructure and knowledge of what marketplace is the most relevant for the specific customer's opportunities for flexibility.

On the Nordic market, the customer's electricity retailer may assume the role as aggregator, or enter into a collaboration agreement with an aggregator with unchanged balancing responsibility for the customer in question. An aggregator may also assume balancing responsibility, or contract a balance responsible party for the customer's total electricity outtake, and thus also assume responsibility for the customer's electricity supply, either by itself or through a partner company. The advantage of the customer's electricity retailer and aggregator being the same entity (or having a civil law contract that regulates their undertakings), is that the design with only one balance responsible party per connection point is maintained. The disadvantage is that where the competition between electricity retailers is small, aggregators may find it difficult to establish themselves on the market, which entails a limited supply of aggregation services.

On the Swedish market, there is thus no opportunity to act as an *independent aggregator*, i.e. to contract customers for aggregated demand side flexibility sold in different markets, independently of the electricity supplier/balance responsible party with which the customer has a contract, and without this party's knowledge or approval. NordREG's report *Discussion of different arrangements for aggregators of demand response in the Nordic market* was published in February 2016 and argues that the Nordic model should not be excluded to the benefit of the model with an independent aggregator. NordREG emphasises that a well-functioning market with good competition between electricity traders and low entry barriers should be sufficient to enable aggregator services to develop. If such circumstances do not exist, there may however be a need for regulation, and the national regulatory authority should then adapt the market rules to enable a market model with independent aggregators (NordREG, 2016).

Opportunities and obstacles

It emerges from the revised Electricity Market Directive that the member states shall define a framework for independent aggregator and for demand side flexibility that follows the principle that these shall be able to participate fully in all markets. The revised Electricity Market Regulation clarifies the principle of balance responsibility, where all actors shall take financial responsibility for the costs they cause to the system. A general obstacle, irrespective of which model is

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[32] COM (2016) 864

[33] COM (2016) 861

implemented, is the risk it entails for the party who needs to invest in the equipment required to enable a plant to participate in the balancing market. This may possibly lead to the party who has invested in the equipment wanting to tie in customers in longer contracts, which is not desirable, as this may cause long-term competition problems in the electricity market.

The **aggregator model implemented in the Nordic countries** today means that the aggregator itself is the balance responsible party, or has an agreement with a balance responsible party. Although the competition between the 30 or so balance responsible parties active in Sweden may be considered as good, in practice an aggregator may for various reasons only have a few balance responsible parties to choose from. An aggregator may also be unwilling to start collaborations that require information to be given to the balance responsible party on the plants to be used. The risk is that the balance responsible party takes over the aggregator's business with its customers.

In purely theoretical terms, there are two different models for **independent aggregator** participation in the market. In the first option, demand side flexibility is regarded as a stand-alone product on the market, and therefore does not have to buy any electricity or compensate any electricity retailer for the bids activated. The justifications highlighted for choosing this model is that the societal benefit, through a general reduction of the price level, is greater than the overall cost arising for the electricity retailers (who have bought the electricity that is re-delivered to the market). Finding a market model that entails the cost of this price reduction effect being distributed within the customer collective without other market-disturbing effects requires in-depth analysis however.

The other option is that both the aggregator and the balance responsible party for the electricity retailer are active and have balancing responsibility for the same connection point. For this, economic redistribution between the parties involved is required. These may be either regulated via market rules, or via contracts between the parties (Smart Grid Task Force, 2015a). Control of how the economic redistribution is to be done risks being complex, in particular on electricity markets with many actors.

According to the proposal in the revised Electricity Market Directive, independent aggregators shall not be responsible for compensating electricity retailers. This option is allowed only as an exceptional exclusion in the proposal.

4.5 Proposed measures within the electricity market area

The proposed measures within the electricity market area are in line with the fundamental principles presented in Table 1. Table 9 shows a summary of proposed measures that can potentially contribute to increased demand side flexibility.

Table 9. Activities, obstacles and measures to stimulate demand side flexibility from a market actor perspective

Activities	Obstacles/Lack of drivers	Measures
Proactive demand side flexibility in the form of more flexible bids on the day-ahead market	Balance responsible parties and electricity retailers lack tools for forecasting sufficiently exactly how customers will act, and will therefore carry a risk	Hourly metering for all customers[34]
	Electricity retailers perceive a risk in marketing hourly price contracts	Daily settlement per hour for all customers[35]
	Contract formats and metering that prevents the price on the day-ahead market from reaching the electricity customer	
	The products on the day-ahead market are not adapted to enable loads to be moved	Work to enable products promoting demand side flexibility (enables moving loads) being offered by the electricity marketplaces
Bids on the balancing market – automatic reserves	The investment climate is problematic, due to marginal pricing not being applied	Investigate how the prerequisites for automatic reserves from the consumer side can be promoted
	Transparency in terms of compensation levels is low	
Bids on the balancing market – regulating power market	Requirements that must be fulfilled to participate in the regulating power market may be obstructive	Investigate how consumption bids can be promoted on the regulating power market
The aggregator role	The aggregator role is currently unclear	Analyse and develop the aggregator role in line with upcoming European legislation and adapted to the Nordic electricity market

Source: Ei

Daily settlement per hour for all customers

A majority of Sweden's customer with connection contracts of no more than 63 ampere currently choose a contract with a variable monthly price. This means that the electricity retail price is based on a volume-weighted average of the month's hourly prices. As the volume-weighting is based on the network settlement area's consumption profile, individual customers cannot impact their electricity retail price by adapting their electricity use according to variations in the hourly price. The price on the day-ahead market therefore does not reach the electricity customers.

To enable demand side flexibility on the day-ahead market, we propose that all customers shall be metered hourly[36] and be settled on a daily basis. In the interim report *Slopad schablonavräkning för timmätta kunder?* (Abolish settlement based on profiled consumption for hourly metered customers?) (Ei R2016:03), we reported an analysis showing that the societal benefit from increased use of hourly price contracts with daily settlement exceeds the additional costs that arise, provided

[34] This measure is addressed in Chapter 3, Customer.

[35] This proposed measure goes further than the proposal presented in the interim report *Slopad schablonavräkning för timmätta kunder?* (Abolish standard offsetting for hourly metered customers?) (Ei R2016:03)

[36] That is to say, electricity customers with connection contracts for no more than 63 ampere who do not already have an electricity retail contract that requires hourly metering.

that the transfer is made in conjunction with investment in a modern metering system.

Work to enable products promoting demand side flexibility being offered by the electricity marketplaces

Existing products where the actors must state absolute price levels are less suitable for flexible consumers who want to impact their electricity cost by moving loads between the hours of the day without impacting overall energy consumption. Absolute price levels on the production side are, ideally, the marginal cost for each given production level. For customers who are able to react to price differences between hours by regulating up during low price hours and regulating down during high price hours, a product where absolute price levels are stated is less suitable. A product that enables these customers is currently lacking.

In the process established by CACM and that includes the development of the electricity marketplaces' products, Ei intends to work to enable products on the day-ahead and intra-day markets that are to be included in the final product list to be adapted for demand side flexibility.

Assignment to Svenska Kraftnät relating to the balancing market

Svenska Kraftnät has started a project aimed at developing a strategy to enable demand side flexibility to function as a reserve for frequency regulation. Ei proposes that Svenska Kraftnät is given the following two Government mandates in this context.

- Inquire how the prerequisites for automatic reserves on the consumer side can be promoted. The inquiry should include prerequisites for introducing marginal pricing of capacity, increasing transparency in terms of price and introducing some kind of support for the investments required to enable participation on the market for automatic reserves.

- Inquire how consumption bids can be promoted on the regulating power market through measures such as introducing electronic activation, options to mark bids with a resting period and reduced requirements for minimum bid size.

In addition to the measures already identified, Svenska Kraftnät should also include the following areas in the inquiry:

- Publication of real time information on the regulating power market, such as price and volume from a demand side flexibility perspective.
- Information on how electricity market actors can proceed to offer bids to the regulating power market.
- Increased information to balance responsible parties on the option that is included in the usage contract to exceed their feed-in and outtake contracts when activating a regulating power bid.
- Evaluation of the requirements set to develop these towards being as permissive as possible of demand side flexibility, without jeopardising operational security.

Analysing and developing the aggregator role

Ei's work on analysing the aggregator role will be continued within the framework for the Nordic and European collaboration with the aim of achieving as efficient adaptation as possible to the Nordic electricity market. As the European legislation on the aggregator role is being developed, this work will be done in several steps.

5 Measures within the electricity network sector

5.1 Regulation of electricity network companies and their drivers for demand side flexibility

Within each area of Sweden, one network company has the sole right to conduct electricity network activities, a *network concession.* Because of these companies' monopoly position, there are rules governing the network companies' incomes and how they may design their tariffs.

In Sweden, the income of network companies is regulated via a revenue cap set for a company's allowed income based on the company's capital base and reasonable operating costs. The aim is to provide reasonable cost coverage and a reasonable return on the capital employed in the network company's operation, at the same time as safeguarding good quality of the company's services. The revenue cap therefore takes into account the quality offered by the network companies (primarily relating to outages) and the extent to which the network operation contributes to efficient use of the electricity network. The requirement for efficient use of the networks is made tangible by incentives introduced by Ei to the network companies to both reduce the proportion of network losses and to even out the network load. Through this provision, the network companies have a clear incentive to stimulate demand side flexibility in their network operations.

The network companies design their network tariffs themselves, on the condition that they do not exceed the revenue cap and that the tariffs are objective and non-discriminatory, and are designed in a way that is compatible with efficient use of the network. Tariffs for local and regional networks shall also be uniform within an area, and must not be designed with consideration for where a connection point is located within the area (Chapter 4, Section 3 of the Electricity Act). At transmission level, the network tariff may, however, be designed with consideration for where the connection point is located (Chapter 4, Section 9 of the Electricity Act).

One opportunity offered by demand side flexibility from a network perspective is a more even outtake, with less notable peaks. A direct consequence of smaller peaks are reduced network losses, as the losses are proportional to the square of the load (CEPA, 2014). A further benefit of reduced power outtake in the networks are reduced costs for overlying and adjoining networks, as these are dependent on contracted or measured power at the interface points. Through demand side flexibility, the network companies can also avoid or reduce the risk of outages (Nylén, 2011; THEMA Consulting Group, 2014)[37]. Demand side flexibility can also be used by network companies to avoid or defer investment in the electricity networks, which are normally several times higher than the cost of flexibility

[37] Outtake limitation can be effected through peak load tariffs or direct load control, for example.

(SOU, 2014). In order for demand side flexibility to be an alternative to network expansion, however, it must be predictable and stable over a sufficiently long period.

The result of a survey carried out by Ei shows that just over 15 per cent of the network companies offer services and programmes for demand side flexibility (Ei, 2015b). Indirect load control, where the customers themselves respond to signals from the tariffs, dominates, but direct load control also exists. Around 20 per cent of the companies that do not offer services for demand side flexibility state that they are positive towards introducing some type of control in the future (Ei, 2015b). More than half of the network companies state that they intend to buy services for demand side flexibility in the future, in particular to reduce the cost of overlying networks, but also to facilitate integration of local production and to reduce network losses (Ei, 2015b).

5.2 Tariff design

To realise the potential demand side flexibility that is available, the network tariffs for transfer of electricity (tariffs) can be used as a tool. Hourly metering and more advanced metering and control systems enable time-differentiated tariffs, power tariffs and direct load control. Based on previous inquiries and opinions from various actors, Ei can see a need for a transition to tariffs that better reflect the costs of the network and stimulate demand side flexibility. Today's tariffs, which are primarily based on energy for smaller customers and contracted power for larger customers, do not always reflect the costs that consumption or feed-in give rise to in the network. As the network operation consists of large fixed costs, the tariff often consists of a large fixed proportion, and this does not stimulate demand side flexibility.

The network tariff has the potential to impact directly on customers' consumption patterns by sending various price signals (Ei, 2012; CEER, 2015; NEPP, 2014). Depending on how the tariffs are designed, the signals can vary and stimulate various behaviours. As this report focuses on demand side flexibility, the analysis is limited to consumption tariffs.

Network tariffs can be fixed or variable, and based on consumed energy (kWh) or power (kW), or combinations of these. The tariff can also be based on contracted power, or fuse size. The design of a network tariff can vary, depending on the definition of the parameters for the fixed and variable parts, the time profile across 24-hour periods and seasons in the event of time differentiation, and any deductions for interruptible load.

In order to stimulate demand side flexibility and changed behaviour, the variable component of the tariff is crucial. Table 10 shows how different versions of the variable part of the network tariff can stimulate customer behaviour. The tariff elements in the table can be combined in various constellations. To avoid a mix-up of tariffs based on contracted and consumed power, tariffs based on contracted power are also included, despite being considered as fixed.

Table 10. Options for the variable part of the network tariff, and the behaviour they might stimulate

	Time-independent	Time-dependent
Based on energy consumption	Reduced consumption Increased energy efficiency	Reduced consumption at specific times Load shifting
Based on power consumption	Reduced power consumption during the customer's own power peaks Load shifting	Reduced power consumption during the customer's own power peaks Load shifting during peak loads
Based on contracted power	Reduced contract Permanently reduced power consumption during the customer's own power peaks	Reduced contract during peak load times Permanently reduced power consumption during specific times

Source: Ei

By giving customers clear information on the design of the tariff and how they can impact on their own costs, network companies can make it easier for customers to be flexible. For more complex tariffs, the need for information increases for customers to respond to the price signals that stimulate demand side flexibility. A high proportion of fixed costs in the tariff and a lack of information about tariff design and customers' opportunities to impact costs lead to both increased customer dissatisfaction and limited opportunities for customers to be flexible (Ei, 2016). A survey carried out by Ei shows that customers are dissatisfied with the network companies' information on tariffs, despite the investigated companies fulfilling the formal requirements for publishing tariffs on their websites (Ei, 2016).

Opportunities and obstacles

The impact of tariffs on demand side flexibility

The potential for tariffs to stimulate demand side flexibility has been analysed in a number of Swedish and international studies. A previous study conducted by Ei (Ei, 2012) emphasises that tariffs that provide incentives to even out power consumption are also positive from an energy efficiency perspective. Such tariffs are designated *capacity-effective tariffs* and are defined as tariffs that are based on both cost and demand conditions, i.e. the price level reflects demand conditions and the load on the network. Examples of tariffs designed to reflect demand are power-based tariffs or energy-based tariffs with noticeable price differences between low and high load periods.

In its final report, the Swedish Coordination Council for Smart Grid Networks emphasised the result of studies showing that network tariffs can provide stronger price signals for demand side flexibility than the electricity price, and thereby raise the potential for network tariffs to stimulate demand side flexibility.

In a report commissioned by the Nordic Council of Ministers, THEMA states that power tariffs, tariffs designed according to marginal losses and tariffs for interruptible loads can increase demand side flexibility (THEMA Consulting Group, 2014). In its assessment of the report, NordREG confirmed the need for tariffs to be designed to stimulate demand side flexibility without compromising on cost-effectiveness, and that tariffs should continue to be non-discriminatory and objective (NordREG, 2014).

The importance of network tariffs that reflect the costs are also highlighted at European level, for example by CEER (CEER, 2015). The EU Commission's Smart

Grids Task Force emphasises the importance of innovative network tariffs with clear price signals to stimulate demand side flexibility. (Smart Grid Task Force, 2015b). Eurelectric[38] also highlights the need for tariffs that stimulate both load shifting and reducing peak loads, and advocate more power-based tariffs (Eurelectric, 2013) . The research consortium S3C has analysed pilot and demonstration projects within demand side flexibility for household customers and small and medium-sized companies, and highlight the opportunities of dynamic tariffs to stimulate flexibility (S3C, 2015).

Other important aspects are a long-term view and transparency in the design of tariffs, and several actors have emphasised the need for stepwise introduction of new tariffs, to facilitate the transition for both customers and network companies. Finally, it is crucial that the design of the tariffs is clear and comprehensible to customers, if the tariffs are to change customer behaviour.

Network companies' opportunities to use tariffs to stimulate demand side flexibility
Different tariff designs have different effects, and therefore provide different benefits for the network company. Studies have shown that a time-differentiated tariff with a pre-set 24-hour profile, with a high fee during high load hours and low fee during low load hours, leads to a more even load. Through a more even load, the network capacity can be used more efficiently, and in the longer term the network company can therefore avoid investments and reduce its capital costs. A more even load has also been shown to reduce losses in the network, which leads to more efficient network operation. A critical peak pricing tariff, on the other hand, provides incentive for customers to change their consumption pattern on one-off occasions each year. Critical peak pricing can lead to more efficient network operation, as increased demand side flexibility during extreme circumstances can reduce the risk of disconnection due to a power deficit.

To enable charging customers based on power or time-differentiated energy consumption, at least hourly metering of consumption is required. With an even higher resolution of metering, for example on 15-minute basis, the opportunities for cost-reflective tariffs are further improved.

Network companies design customer groups according to fuse size, which was originally due to lack of meter data and limited information on customers' consumption patterns (Ei, 2012; Helbrink, et al., 2015). With access to customers' consumption profiles showing their consumption over time, it is possible to investigate which customers have similar consumption patterns, which enables new customer classifications. Network companied have the option of identifying new customer categories, as long as the classification is objective, transparent and cost-reflective. An alternative customer classification could enable the introduction of tariffs aimed at customers with specific consumption patterns and switching potential, such as customers with electric heating.

Obstacles for network companies offering tariffs that stimulate demand side flexibility
The provisions in the Electricity Act on tariff design are general and leave lots of freedom to network companies. As long as the requirements for objectivity and

[38] The Union of the Electricity Industry – the European sector organisation for the electricity industry.

non-discrimination are fulfilled, network companies are free to design their own tariffs. The requirements for objectivity and non-discrimination in the Electricity Act does, however, impact the network companies' opportunities to design and launch new tariffs. The opportunities to test new tariffs on a small scale before they are offered to the entire customer collective are limited. This is a particular obstacle when network companies want to test new tariffs within the framework of pilot projects. According to the network companies, pilot projects have great potential for improving the tariffs launched, as they are then thoroughly investigated and analysed before being launched on a major scale. Furthermore, new tariffs be applied to the entire customer segment simultaneously. When changing to significantly different tariffs, it can however be desirable to launch the tariff gradually. It is then easier to implement targeted information campaigns, which in turn would improve the acceptance of the new tariff, and customers' opportunities to respond to price signals.

Congestion in a local network often arises within a limited area, which could be an argument for introducing tariffs that vary geographically within the local network. This diverges from the provision in the Electricity Act that local and regional networks are not allowed to differentiate tariffs based on where a connection point is located. This prevents network companies from designing cost-reflective tariffs, as they would sometimes entail local variations within the network.

The obstacles detailed above are also raised by the network companies that Ei has had contact with. Furthermore, there is uncertainty among network companies about future regulations, linked to tariff design, and new prerequisites, linked to factors such as the introduction of a supplier-centric model in Sweden. Network companies have also voiced concern about cost coverage when new tariffs are introduced. With tariffs that increasingly vary according to consumption, for example with a reduced fixed part, or a power-based component, the difficulty for network companies to predict their tariff income increases. Ei, however, considers that the problem of cost coverage is limited given the regulatory model implemented in Sweden, as any under- or over-financing from tariffs can be adjusted over the entire revenue cap period, which is four years. Another problem raised by the network companies is the difficulty of communicating a new tariff to customers. The communication problem has been raised in relation to power tariffs in particular. This corresponds to complaints received by Ei's customer services function Konsumentkontakt[39], where individual companies that have introduced power tariffs have been over-represented among complaints about tariffs. There are, however, good examples of how power-based tariffs have been introduced and communicated clearly to customers, without any significant increase in complaints as a result.[40]

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[39]Konsumentkontakt is the function at Ei that communicates with consumers on the energy markets, for example by answering questions and receiving complaints.

[40] See for example the information brochure from Karlstads El- och Stadsnät, http://www.villaagarna.se/Lokalforeningar/mitt/karlstad/L%C3%A4rdigmer_effekttariff_Karlstads%20eln%C3%A4t.pdf or information from Sandviken Energi AB on the introduction of power tariffs for all customers with fuse sizes of 35-63 A in May 2015, https://sandvikenenergi.se/elnat/elnatsavgifter/effektariff3563a/nyeffekttariff.4.7d891c141558be64f17f1672.html

5.3 Direct load control

There are two types of load control, indirect and direct load control. The load control that network companies can achieve through tariffs is indirect load control. Through direct load control, network companies can directly impact their customers' consumption via controllable loads. This can be done through hard disconnection, when pre-selected loads are disconnected over a specific period, or soft disconnection, when the load is reduced over a period (Nylén, 2011). The load control can be carried out across the entire connection point, or at component level, where an individual device, such as a heat pump, can be controlled.

Direct load control gives network companies the opportunity to manage capacity limitations in the short term, and in this way maintain the reliability and quality of their networks (Eurelectric, 2014). In the long term, direct load control can reduce the need for capacity investments. Contracts for direct load control could be entered into direct between a network company and its customer, or be procured by network companies from an external actor (energy service company or aggregator), who in turn enters into a contract with the customer.

Some types of load control are used by network companies today, via tariffs for interruptible load, such as disconnection of electrical heaters during peak periods in the network. With these tariffs, customers have an agreement to disconnect the heater themselves, following a signal from the network company. It is thus the customer and not the network company who is responsible for the disconnection.

The document *Energy regulation: A bridge to 2025* makes several references to demand side flexibility and direct load control (ACER, 2014). The report highlights demand side flexibility as an important means for network companies to make their operations more efficient, to the benefit of customers. Despite the advantages of direct load control for network companies, ACER and CEER emphasise the importance of this not occurring at the expense of competition in the market, and that network companies shall use their roles as neutral facilitators. CEER also addresses direct load control for network companies in the report *The future role of DSOs* (CEER, 2015). CEER points to the importance of developing tools for regulating network companies' contracts relating to flexibility. Flexibility shall be procured in a non-discriminatory, market-based, transparent and efficient manner. CEER does however accentuate that there might be reason to let network companies enter bilateral flexibility contracts with customers in specific geographic areas, where the need from a network perspective is the greatest, as long as this does not limit the flexibility of other actors.

The EU Commission's Smart Grid Task Force has also highlighted the role of network companies in enabling and using flexibility, and at the same time emphasises the importance of national regulatory authorities removing obstacles to network companies procuring flexibility (Smart Grid Task Force, 2015b). In a report from 2014, EDSO[41] for Smart Grids presented the role of network companies in the electricity market of the future, focusing on demand side flexibility and the benefits network companies can experience (EDSO, 2014). It accentuates the

[41] European Distribution System Operators

opportunities of network companies to procure direct load control in order to maximise supply security and quality in an efficient manner.

Different types of load control

One way for network companies to achieve load control is to contract the right to disconnect customers at certain times, procurement of demand side flexibility direct from customers or via an aggregator. The procurement should be possible similarly to the TSO Svenska Kraftnät's strategic reserve and be used by the network company in the event of local network limitations, or to reduce the cost of network losses or overlying networks.

The control of the connection point can be exercised directly in the meter, meaning that the whole or part of the load is disconnected. Network companies may only carry on operations within their concession area, which extends to the connection points, i.e. the meter.

Another way for network companies to achieve direct load control is to give incentives for customers to reduce their own loads. Customers can then choose for themselves how much of their load shall be reduced, and how the reduction shall be made. Customers can choose to make manual adjustments of consumption, or to install some type of control equipment, for example in a heat pump.

Opportunities and obstacles for network companies to use and promote direct load control

A number of pilot projects have been carried out that indicate a potential for load control to achieve demand side flexibility. They also show that customers are interested in load control, provided they get sufficient financial incentives (prices and tariffs), and that there are technical solutions to help them (Nylén, 2011). For network companies, the benefits of load control are primarily lower costs for overlying networks, lower network losses and lower costs of network investments or opportunities to defer investments (Nylén, 2011). Large savings are possible in particular when the network company is at risk of exceeding the contracted power to the overlying network.

The technical prerequisites for implementing direct load control are good, and there are several energy service companies offering services for load control both directly to customers and to network companies. The opportunities for network companies to buy services to control their customers loads are not limited by any regulations. Network companies can therefore enter into contracts with energy service companies, for example, to reduce the consumption within an area. The cost of the load control needs to be handled within the revenue cap regulation, however.

In order to remotely control customer loads at plant level, such as heating and cooling, control equipment within the customer's premises is required. The network company can contract that the special equipment needed for control at plant level is installed and owned by the customer, or by a third party actor. What is then required is for the network company's compensation to the customer to be sufficiently large for the customer to decide that an investment in the control equipment is profitable. Network companies have so far shown little interest in this type of direct procurement of control, and a previous survey carried out by Ei (Ei, 2015b) also showed that it was considered expensive to install equipment required for load control, in particular for direct remote control of customers' plants (Ei, 2015b).

Another obstacle to load control is that there are no rules for compensation for network benefit from consumers. The Electricity Act regulates compensation for network benefit for production plants (Chapter 3, Paragraph 15), where the value of the compensation shall correspond to:

1 the value of the reduced energy loss that feed-in electricity from the plant entails to the network; and
2 the value of the reduced network fees to overlying or neighbouring networks for the network owner, resulting from the production plant being connected to the network.

With the corresponding rules for consumption facilities, the opportunities for consumers to contribute with demand side flexibility would increase.

5.4 Proposed measures within the electricity network area

The activities that network companies could implement to promote demand side flexibility, and that were presented in the section above, are today implemented only to a limited extent. The proposed measures within the areas *tariff design, direct load control* and *other* are presented in Table 11. The measures proposed fulfil the fundamental principles identified in Table 1.

Table 11. Activities, obstacles and measures for network companies to stimulate demand side flexibility

Activities	Obstacles or lack of drivers	Measures
Tariff design	The regulator has limited control over how tariff design Prohibition against testing tariffs within the framework for pilot projects Prohibition against introducing tariffs gradually Lack of information to customers relating to tariffs Requirement for hourly metering only for customers with hourly retail price contracts	Authorisation to issue regulations for how tariffs shall be designed to promote efficient use of the electricity network Permit gradual introduction of new tariffs and pilot projects relating to tariffs Information requirement for tariffs and other opportunities for cost savings Hourly metering and access to hourly values for all customers[42]
Direct load control	No regulation of network benefit from consumers Requirement for hourly metering only for customers with hourly retail price contracts Lack of information on flexibility potential	Investigate whether compensation for network benefit can be given to actors other than producers, such as consumption plants Hourly metering and access to hourly values for all customers[43] Voluntary reporting of flexibility potential to the service hub[44]
Other	Lack of incentives for efficient network use	Evaluation of incentives in the electricity network regulations aimed at making efficient use of the electricity network

Source: Ei

[42] This measure is addressed in Chapter 3, Customer.
[43] This measure is addressed in Chapter 3, Customer.
[44] This measure is addressed in Chapter 3, Customer.

Authorisation to issue regulations for how tariffs shall be designed to promote efficient use of the electricity network

There is much evidence that time-differentiated network tariffs may be necessary to promote efficient use of the electricity network. However, special authorisation from the Government is necessary to enable Ei to issue instructions on tariff design. We therefore propose that Ei be given such authorisation, at the same time as the fundamental principle is retained that network companies shall continue to be able to design their own tariffs. Instructions on efficient network tariffs should therefore primarily define the components necessary to achieve the goal of efficient use of the electricity networks.

An instruction on how network tariffs shall be designed for efficient network use would lead to more harmonised tariffs and less uncertainty among network companies on how tariffs should be designed. For customers, this might lead to clearer and more cost-reflective tariffs.

Mapping of tariff design

Ahead of producing instructions on tariff design, a thorough mapping and evaluation of existing tariff designs in Sweden is necessary. The evaluation must focus on how tariffs are designed, and whether they are designed in a way that is compatible with efficient use of the electricity network, and efficient electricity production and electricity use. At the same time, it should provide opportunities to learn from the good examples that exist of tariff design that stimulates demand side flexibility.

Network companies are already reporting in all their tariffs to Ei, but these need to be supplemented with an explanation of how the tariff has been calculated, and how its construction promotes efficient use of the electricity network, and efficient electricity production and electricity use. The results can be used both to stimulate improved tariffs for all network companies, and as supporting documentation for an instruction on tariff design.

Tariffs shall be time-differentiated and based on the usage of the network in question

The advantage of time-differentiated tariffs is that the reduction can be achieved when the needs of the network or the system are the greatest. Time-differentiation of tariffs therefore contributes to increased cost-reflectiveness and increased incentives for demand side flexibility. Both energy and power tariffs should therefore be time-differentiated and the option of power tariffs should therefore remain. On the other hand, power tariffs without time-differentiation would perhaps not be considered cost-reflective, as high power consumption during low load periods is not cost-driving for the electricity network.

The time-differentiation needs to be based on the usage of each network in order for demand side flexibility to be used at the correct time. Tariffs shall be objective and non-discriminatory, and it is therefore not possible to justify time-differentiated tariffs where the timings of high and low loads do not reflect the usage of the network in question. Ei therefore proposes that, when instructions are produced, one requirement shall be for time-differentiation that reflects the network’s load to be analysed. The time-differentiated tariffs used today are often divided into two parts, but Ei can see that for some networks, several levels may be required. One example could be a three-part tariff, that is highest during the morning and evening peak loads, lower during the day and lowest during the night. As the measure would be implemented within the framework of the authorisation proposed by Ei, there is no need for any other changes to the regulations.

Permit gradual introduction of new tariffs and pilot projects relating to tariffs

Ei proposes that the Electricity Act is changed to permit gradual introduction of new tariffs. This means that the need for information and education campaigns can be spread out over time, as well as any investments in smart meter systems. The fact that tariffs must be uniform within a network area and for a customer category also means that new tariffs cannot be launched and tested within the framework of a pilot project unless it applies to an entire customer category. Pilot projects give network companies the opportunity to try out a tariff within a limited group, both for any necessary adjustments and for reducing the risk of introducing new tariffs on a major scale. The proposed change to the Electricity Act should include this purpose as well.

One risk of the change in regulations is that it could create dissatisfaction among customers who feel that they are either not given the chance to use a new tariff, or that they are forced into something that the rest of the customer collective can avoid. This risk could however be minimised through targeted communication efforts. The new tariff also needs to be constructed so that it is primarily the design and not the level that changes. In this way, the financial effect on individual customers of the gradual implementation will be limited.

Information requirement for tariffs and other opportunities for cost savings

To increase customers’ opportunities to respond to financial signals in the network tariff, we propose a more comprehensive information requirement for network companies. With increased demands on network companies to explain their tariffs and how these in combination with the customer’s consumption impact on the overall cost, the price signals in the tariff would reach their target more effectively. This applies in particular to more complex tariffs, such as time-differentiated or power-based tariffs. This measure is considered crucial for the other measures within the tariff area to have the desired impact.

The information that network companies provide about their tariffs varies greatly from company to company. The measure is made tangible through a proposal for a change in the Electricity Act, stating that the holder of the network concession shall inform electricity users on issues such as how network tariffs are designed, and what the options are to impact costs by switching tariffs or by changing

Investigate whether compensation for network benefit can be given to actors other than producers, such as consumption plants

Network benefit compensation is currently paid to producers for the benefit they create for the electricity network in the form of lower network losses and lower costs for overlying networks. With more sun and wind, which cannot contribute inertia and reactive power in the same way as the traditional forms of energy, there may be a need among network companies to compensate actors for savings other than for network losses and lower costs for overlying networks. In addition to consumers, aggregators may contribute network benefits, for example. Ei therefore proposes an inquiry into which further actors can contribute and be compensated for network benefits, and how the compensation should be calculated.

Network benefit can vary, depending on where in the network it arises, and a load-controlled customer can therefore create more benefit for handling local network problems. Ei sees network benefit as a complement to correct tariffs, where the primary advantage of regulating this separately is that network benefit can vary, depending on where in the network it is added, as opposed to tariffs, which must be uniform within a customer category. The measure can also be considered to strengthen customers' opportunities to receive compensation for the flexibility they contribute to the network.

As the calculation and payment of network benefit impacts the network companies' costs, the measure should also be linked to the proposed review of the incentive regulation below.

Evaluation of incentives in the electricity network regulations aimed at making efficient use of the electricity network

As from the regulatory period 2016–2019, there are incentives for efficient network use within the framework for Ei's revenue cap regulation.[45] The incentives have however been criticised for being too weak. To investigate how the new incentives are working, and to analyse the need for adjustments, we propose a review and evaluation of the incentive regulations.

In line with the fundamental principle that our measures shall primarily have a long-term effect, Ei considers that an evaluation and review of the existing incentives shall be carried out as a first step. The result of the review could then be used to develop the incentives, add new incentives or make other adjustments to the incentive regulations. The primary purpose is to reinforce the incentives for network companies to make their operations more efficient, where the use of demand side flexibility could be a possible tool. The measure lies within the activities of Ei, and can be implemented without any change to legislation or any specific mandate.

[45] EIFS 2015:6

6 Measures within the area of taxes and support systems

The Swedish Government's energy policy aims to create prerequisites for efficient and sustainable energy use, and cost-effective energy supply with low negative impact on health, environment and climate, and facilitate the transition into an environmentally sustainable society[46]. The aim of Swedish electricity market policy is also to achieve an efficient electricity market, with well-functioning competition, that provides secure access to electricity in both the short and long term, at internationally competitive prices[47].

Market and legal obstacles to market-driven demand side flexibility can be removed by the government through financial and administrative measures, such as taxes, support systems and regulations (such as building standards). A further way for decision-makers to impact the development of energy markets is through support to research within the energy area. Taxes and support systems can also be used to reinforce price signals to customers, or to make it more profitable to invest in equipment or plants that enables demand side flexibility.

Taxes and support systems have varying purposes, and the outcome of introducing a tax or a support system is ultimately dependent on the market prerequisites for the specific sector. For the energy sector, taxes are used both to generate tax income (so-called fiscal taxes), and as a means of control to achieve set environmental goals. An important criterion for a fiscal tax to be goal-effective is that the tax base is stable over time. The purpose of taxes and support system directed at a set environmental goal, for example, is to impact the behaviour of market actors. The tax base then reduces as behavioural changes occur.

6.1 Taxes and support systems linked to the energy sector

Energy taxes

Energy taxation is a collective term for selective taxes on fuels and electricity. Energy, carbon dioxide and sulphur taxes are regulated by the Energy Tax Act (SFS 1994:1776), while the nitrous oxide charge is regulated in the Act on an Environmental Charge on Emissions of Nitrogen Oxides in Energy Production (SFS 1990:613).

Energy tax is payable on most fuels and is based on their energy content, among other factors. All electricity consumed in Sweden is generally liable for tax, and the tax is paid by the end consumers. Electricity production in Sweden is covered by the EU's system for trading in emission rights, but is otherwise free from energy

[46] http://www.regeringen.se/regeringens-politik/energi/mal-och-visioner-for-energi/
[47] http://www.regeringen.se/regeringens-politik/energi/energimarknader/mal-for-energimarknader/

and carbon dioxide taxes (the fuel used by the producers themselves is taxed, however).

The carbon dioxide tax is paid per emitted kilogram of carbon dioxide for all fuels except biofuels and peat.[48] The sulphur tax is based on the sulphur content in coal, peat and oil. The nitrous oxide tax is paid per emitted kilogram of nitrous oxide for combustion plants generating at least 25 GWh per year.

All electricity production plants pay an industrial property tax that varies between plant types. For hydro power plants, the industrial property tax amounts to 2.8 per cent of the property's value for taxation purposes, while for wind power plants it is 0.2 per cent. Other electricity production plants pay 0.5 per cent.

Currently, nuclear power producers pay a separate power tax, based on the maximum permitted thermal power of the reactors, in addition to the 0.5 per cent property tax. This tax is currently 14 770 SEK per MW and month. A further charge of 0.003 SEK per kWh is charged according to the "Studsvik Act"[49], and an average of around 0.04 SEK per kWh is paid to the nuclear waste fund.

A cross-party energy agreement reached in the Riksdag (the Swedish parliament) in 2016 entails that the special property tax for hydro power stations and the power tax on nuclear power shall be abolished gradually as from 2017. Financing of the abolished and reduced taxes shall be made through an increase in the energy tax (Ministry of Finance, 2016).

The electricity certificate system

The electricity certificate system, which is regulated in the Act on Electricity Certificates (SFS 2011:1200), is a market-based control tool aimed at achieving the national goal for renewable electricity production in Sweden. The electricity certificate system is financed by the electricity customers.

For each MWh of renewable electricity produced, the electricity producer receives an electricity certificate. The producers can sell the electricity certificates to electricity retailers, who are obliged to buy a certain number of electricity certificates in relation to their electricity sales. The electricity producer then receives an extra income from the electricity production in addition to the wholesale price. The demand for electricity certificates is created through electricity retailers and certain electricity users[50] being obliged by law to buy electricity certificates corresponding to a certain proportion (quota) of their electricity sales or use. In this way, a market for electricity certificates is created. The proportion of certificates to be bought (the quota) is regulated in law, and varies from year to year. The cost (the market price) of electricity certificates is included as a component in the retail price for electricity. The market price of

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[48] The basis for the carbon dioxide tax can be summarised as being the fossil fuels covered by the EU's Energy Tax Directive, which means that biofuels are not covered by the tax.

[49] Act on the Financing of Certain Nuclear Waste (SFS 1992:1537) (Studsvik Act).

[50] Electricity-intensive industries registered with the Swedish Energy Agency are entitled to a deduction when calculating the quota obligation for the electricity used in the manufacturing process.

electricity certificates varies, and depends on when the electricity retailer bought the electricity certificate, the quota for the year, and the type of electricity contract.

Over the years 2003–2015, the market price of electricity certificates has varied between 0.015 and 0.053 SEK per kWh. In 2014, an electricity certificate cost 0.028 SEK per kWh on average.

The EU's system for trading in emission rights

The EU's system for trading in emission rights[51] aims to limit emissions of greenhouse gases. By pricing the environmental costs associated with greenhouse gases, the hope is that market actors[52] will reduce their emissions.

The system is based on an annual ceiling being set for how large overall emissions can be (the ceiling is lowered every year), and that emission rights corresponding to this ceiling level are issued. The companies must then report back that their actual emissions do not exceed the emission rights they hold. If a company has emissions that are higher than the emission rights it holds, it can either buy more emission rights on the market or invest in measures to reduce their emissions. A company that emits less carbon dioxide than its issued emission rights can either save the emission rights to the next year or sell the surplus to other companies (Swedish Energy Agency, 2016).

6.2 Areas where decision-makers can impact the development of demand side flexibility

There are several areas where decision-makers can impact the development of demand side flexibility. We have divided up the areas into taxes, support linked to the functioning of the market, and investment support.

The impact of taxes on demand side flexibility

The retail price of electricity is directly impacted by the energy tax on electricity (electricity tax), electricity certificates and value added tax (VAT), and indirectly by other energy taxes where the tax is charged on electricity production. The customer's electricity cost consists of the costs of distribution (electricity network), the electricity (retail) and taxes. The customer's overall electricity costs consist to a fairly large extent of taxes; depending on the size of the network charge and the retail contract, the tax amounts to slightly more than 1/3 of the total electricity cost.

Energy tax on electricity (electricity tax) and electricity certificates are designed as fixed surcharges on the spot price, while the VAT consists of a percentage surcharge on all the components of the retail price, including electricity tax and electricity certificates. The electricity tax is differentiated depending on who is consuming the electricity, and where it is consumed geographically. In very

[51] EU Emission Trading Scheme, EU ETS

[52] Plant covered by EU ETS are combustion plant with an installed capacity of more than 20 MW and smaller plant connected to district heating networks with a total capacity of more than 20 MW. In Sweden, the majority of the energy plants connected to district heating networks are therefore covered. Other facilities that are covered are mineral oil refineries, coking plant, iron and steel industry, mineral industry (cement, lime, glass and ceramics), paper and pulp industry, aluminium manufacture, and flight operations within the EEA.

simplified terms, households and the service sector are charged a selective tax of 0.294 SEK per kWh, while the tax rate for industrial operations and manufacturing ("electricity-intensive industry") is in line with the EU's minimum level of 0.005 SEK per kWh (SOU, 2015). The justification for the tax rate being differentiated between different electricity users is that industry is exposed to international competition, and therefore risks losing out if the electricity price is considerably higher than in competitor countries.

Electricity tax, electricity certificates and value added tax (VAT) disrupt the price signal to electricity users, as the electricity price no longer reflects society's actual costs for production. These result in reduced electricity use through energy efficiency measures, primarily among households and the service sector. Furthermore, it impacts the relative price of electricity compared to other input goods, which can make electricity less competitive, for example for heating. A good example is district heating producers, who are obliged to pay electricity tax as they use electricity as an input good in heat production. The impact of electricity tax on the price of electricity can then cause the district heating producer to choose another input good for heat production, despite a low electricity wholesale price.

Demand side flexibility aims to make electricity customers adapt their electricity use according to various price signals. The retail price is expected to play a central role when customers plan their energy use. A future with increased demand side flexibility in the form of reduced electricity use can therefore entail a less stable tax base from households and the service sector. If, on the other hand, customers move their electricity use from one point in time to another, the tax base will not be affected.

Opportunities and obstacles for demand side flexibility – energy tax, electricity certificates and VAT

We have analysed the impact of the taxes on customers' demand side flexibility, based on the forms of demand side flexibility reported in Chapter 2 and a number of alternative behaviours among customers.

Electricity tax and electricity certificates constitute fixed surcharges, while VAT consists of a percentage surcharge. The percentage surcharge means that the skewing effects are smaller, the lower the electricity price. As the VAT reinforces the price difference between hours in both absolute and relative terms, the incentive for electricity users to move their loads over time is enhanced because of the VAT.

The effect of electricity tax and electricity certificates on retail customers' incentives to move loads is dependent on the users' ability to understand and act on the price signal. Electricity tax and electricity certificates dampen the price signal for retail customers who react to relative price differences between hours. On the other hand, they do not impact the price signal for customers who are only concerned about absolute price differences between hours.

Typical consumer 1, who is flexible without moving consumption over time

Customers can be flexible by *reducing or increasing their consumption temporarily* during hours with high or low prices without compensating for this later. An example of this type of flexibility is a district heating producer who uses electricity as an alternative input good in the district heating production when the electricity price is low, i.e. a type of consumer who reacts to the electricity price in relation to the price of another input good. Another example is an industrial customer who reduces production during periods of high electricity price, i.e. a type of consumer who reacts to the electricity price without having a substitute for electricity.

Taxes designed as a fixed surcharge can be expected to impact the behaviour of this type of customer. For example, zero prices or negative prices on the wholesale market indicate a surplus in the electricity system, and that electricity producers are giving away electricity free of charge, or even *paying* the customer to consume electricity during a particular hour. The energy tax means, however, that the electricity customer must still pay 0.294 SEK per kWh[53], excluding electricity certificates, network tariffs and VAT. The electricity tax therefore disrupts the price signal, as the electricity price no longer reflects society's real costs for production.

As the VAT affects the retail price for household customers[54], this tax also affects the retail price and can lead to demand for electricity falling. The VAT on electricity, like other taxes, therefore contributes to weakening the price signal to customers, which can give rise to welfare losses. As the VAT is designed as a percentage surcharge, the welfare losses will however fall the lower the electricity price is. As the VAT is added to all input goods, electricity and the alternative, it does not impact the relative price, and therefore the actions of typical consumers who alternate between different input goods are unaffected.

<u>Typical consumer 2, who moves the load between hours</u>
Customers can be flexible by reacting to price variations over a 24-hour period by *moving the load between hours* depending on where the price difference is the greatest. This type of flexibility entails a temporary decrease or increase compensated for with a subsequent increase or decrease. An example of this type of flexibility is a customer living in a single-family dwelling with a controllable heat pump, who lets the heating inertia in the house function as energy store. Another example is a battery storage that allows more electricity to be bought during low-price hours and saved for consumption during high-price hours.

Typical consumer 2 only reacts to price variations between hours, and moves the loads depending on where the difference in the retail price is the greatest. This type of consumer can react to *relative* or *absolute price changes* between hours when faced with the decision to implement measures that enable moving the electricity consumption.

Typical consumer 2 who reacts to relative price changes between hours will be flexible when the percentage price change is sufficient. The electricity tax means that the percentage price change on the wholesale market does not have the same percentage impact on the retail market, which is illustrated in the mathematical example in Table 12.

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[53] The energy tax for district heating plants is lower if the heat is to be used within manufacturing industry.
[54] Companies offset incoming VAT against outgoing VAT.

Table 12. Mathematical example where a typical consumer reacts to relative price changes between hours

Marketplace	Price hour 17: P_{17}	Price hour 18: P_{18}	Relative price change: $\frac{\Delta P}{P_{17}} * 100$
Electricity wholesale market: Price = electricity wholesale price	20	40	100 %
Retail market: Price = (electricity wholesale price + retail + electricity certificate + network tariff + electricity tax) * (1 + VAT)	100	125	25%

Source: In-house calculation

For typical consumers who only react to *relative* price changes, fixed surcharges, such as electricity tax and electricity certificates, will disrupt the price signal (in percent) to the retail customer. VAT charged as a percentage reinforces the price signal, however (both in relative and absolute terms) on the retail market.

The other type of electricity customer reacts to absolute price changes instead, and calculated what the difference in the retail customer price between hours will entail in terms of kronor and öre, and then relates this saving to the costs of being flexible. Table 13 displays the same mathematical example as above, and shows how large the impact of a given absolute price change on the wholesale market would be on the retail price.

Table 13. Mathematical example where typical consumer 2.2 reacts to absolute price changes between hours

Marketplace	Price hour 17: P_{17}	Price hour 18: P_{18}	Relative price change: $\frac{\Delta P}{P_{17}} * 100$
Electricity wholesale market: Price = electricity wholesale price	20	40	0.20 SEK
Retail market: Price = (electricity wholesale price + retail + electricity certificate + network tariff + electricity tax) * (1 + VAT)	100	125	0.25 SEK

Source: In-house calculation

For typical consumers who only react to *absolute* price changes, fixed surcharges, such as electricity tax and electricity certificates, will not disrupt the price signal (in absolute terms) to the retail customer. VAT charged as a percentage reinforces the price signal (both in relative and absolute terms) on the retail market.

Alternatives to the existing energy tax on electricity

In this project, we have made a summary analysis of a number of alternatives to the existing electricity tax. The project has, however, chosen not to present any specific measure in this area, but instead proposes that a thorough review of the tax issue is carried out from a flexibility perspective.

A **proportional electricity tax** instead of a static selective tax would result in price variations on the electricity wholesale market having a greater impact on the retail price of electricity. Even if the current electricity tax does not impact the absolute price difference between hours on the retail market, it does reduce the percentage impact of the wholesale price and network tariff on the electricity retail price. A proportional energy tax is dynamic in the sense that it varies with the wholesale price and therefore reinforces the price volatility on the retail market, both in absolute and relative terms.

If the energy tax was made dynamic, it would reinforce the price variations on the retail market and thus contribute to increased demand side flexibility. It is however not obvious why the price signal on the retail market must be reinforced by the magnitude that the tax would entail. It is difficult to achieve both a fiscal goal (approximately 20 billion SEK government income), at the same time as encouraging a socioeconomically optimal level of demand side flexibility.

Another option that has been discussed is **reduced electricity tax for all customers, or for certain customer groups.** To minimise the welfare losses to which fiscal taxes give rise, they should be designed to disrupt the market as little as possible. The welfare losses caused by the energy tax on electricity are expected to increase in a future with increased demand side flexibility and more price-sensitive electricity customers, as they dampen the price signal to customers. An energy tax on electricity also makes electricity less competitive compared to other input goods, which risks delaying the transition to renewable energy.

The energy tax also changes the relative price of different input factors, which impacts the behaviour of customers who can substitute electricity by other energy carriers. Having different levels of energy tax depending on whether customers can substitute electricity by other input goods primarily for heating can create incentives for more efficient resource use. For example, if district heating producers were to pay a reduced level of energy tax, they could contribute more than today by using electricity for heat production during hours of electricity surplus and low wholesale prices. The probability of such situations increases as more wind power is available in the system. Vattenfall states that Sweden's existing district heating system can take care of all Swedish wind power produced for several hours in order to manage a situation with surplus electricity[55].

Support linked to the functioning of the market (strategic reserve)

The strategic reserve is procured by Svenska Kraftnät ahead of each winter. It is also Svenska Kraftnät that activates the reserve on the occasions when a deficit situation is expected to arise. Svenska Kraftnät procures the strategic reserve by entering into contracts with electricity producers to reserve their production capacity and with electricity customers to reduce their electricity consumption. The actors participating in the strategic reserve receive a fixed remuneration for reserving capacity, which means that the reserve can be regarded as a support system for increasing security of supply. The strategic reserve is financed through a fee charged to balance responsible parties.

Since April 2014, the proportion of the strategic reserve procured through contracts for reduced electricity consumption shall be at least 25 per cent[56]. Consumption

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[55] Montel-Kraft-Affärer Number 18, 2016
[56] Ordinance on a change to the Strategic Reserve Ordinance (SFS 2010:2004)

tenders therefore do not compete directly with flexible production in the procurement, and different equilibrium prices are established for the various flexibility resources. Ahead of winter 2016/2017, Svenska Kraftnät chose to reserve 34 per cent of the strategic reserve for consumption tenders.

The requirements also differ for production tenders and consumption tenders. While production tenders shall endure for 100 hours, consumption tenders only need to endure for 2 hours, with a recovery period of 6 hours. To participate in the strategic reserve, there is also a requirement for consumption reduction to be implemented within 15 minutes.

Opportunities and obstacles – support linked to the functioning of the market (strategic reserve)

Ei sees both opportunities and obstacles of having a strategic reserve from a demand side flexibility perspective. An energy-only market requires deficit prices to have full impact on the electricity market. Only then will the actors receive the correct incentives to invest in top load capacity or undertake measures to enable demand side flexibility. With the current design, the strategic reserve (if activated) will dampen price variations in various market places and thereby reduce profitability for flexibility resources in other parts of the electricity market – in production as well as consumption. One opportunity of the strategic reserve is that it might trigger consumers' interest in being flexible, while being a marketplace where demand side flexibility is favoured by having a quota share of the strategic reserve. The low average cost of the consumption tenders also indicate that the consumption tenders are cost-effective in relation to the production tenders.

As the purpose of the strategic reserve is that it will be replaced by market-based measures, such as demand side flexibility, in the long term, we do not propose any specific measures within this area.

Investment support – impact on demand side flexibility

Decision-makers have the opportunity to use various types of support systems to reinforce customers' drivers to be flexible. This can, for example, involve support for various technologies to enable demand side flexibility. If the overall personal financial incentives for carrying out an investment are smaller than the benefit to society, a socioeconomically optimal level of demand side flexibility will not be achieved. If this is the case, it might justify the government financing investments in new flexibility resources (Malcolm, 2001).

The fundamental question that decision-makers must ask themselves is whether the market or the technology for demand side flexibility is associated with positive external effects, such as learning effects, or if it contributes to increased security of supply or other welfare gains. It is also important to evaluate and design the means of control so that the amount of welfare gains is at least as great as society's cost for financing the subsidy (Walawalkar, et al., 2008).

Opportunities and obstacles – investment support

Although demand side flexibility has been mentioned often in the debate in recent years, it still constitutes an immature market. Energy service suppliers who niche themselves with services that enable automatic load control must invest considerable resources in educating customers about the advantages of demand side flexibility. The educational investments made by individual companies in this area can disseminate across the market, so that the company's competitors can enjoy lower entry costs to the market in the future (Van Benthem, et al., 2008).

Dissemination effects on a market can arise in conjunction with projects that include new technology or generate new knowledge (Broberg, et al., 2010). Positive dissemination and environmental effects that are not priced on the market mean that the profitability of the projects is greater for society than for the project owners. The rate of investment will therefore be lower than is socioeconomically justified, which might justify the government contributing financially. Ei has identified that support for control equipment in heating plants at customers' premises (such as heat pumps) and energy storage could potentially provide this type of dissemination effects, at the same time as the technology contributes to increased demand side flexibility.

Subsidies are already given to individuals (Ordinance SFS 2016:899) for installation of systems to store their own production of electricity. The requirement set for the systems eligible for subsidies is that they must be linked to a plant for own production of renewable electricity that is linked to the electricity network. This will contribute to storage of electricity for use at a time other than the time of production, and to increasing the annual proportion of own production of electricity used within the property to fulfil the own electricity need. The grant may cover a maximum of 60 per cent of the eligible costs, however maximum 50 000 SEK. The grant is time-limited and may only be paid for measures started after 1 January 2016 and concluded before 31 December 2019.

A subsidy to encourage demand side flexibility results in some electricity users becoming more price-sensitive due to the reinforced financial incentives to adapt their power consumption. The welfare gains that arise through this increased price-sensitivity must be weighed against the costs incurred by society through financing the subsidy. A support system may also impact customer behaviour in ways other than merely through the price signal. The signal value of a support system can contribute to highlighting demand side flexibility as important. The increased marketing of demand side flexibility can therefore contribute to making electricity customers even more price-sensitive by making them aware of the advantages of adapting their power consumption according to various signals.

Investment support for energy storage or control systems can therefore be justified on socioeconomic grounds if the welfare gains from increased price sensitivity resulting from the investment are at least equal to the cost of the subsidy. Exactly how large the welfare gains will be is difficult to estimate, as investment support may lead to benefits at several levels in the electricity system.

6.3 Proposed measures within the area of taxes and support systems

This section summarises Ei's proposals for measures. The measures within the area of taxes and support systems are shown in Table 14, and are in line with the fundamental principles presented in Table 1.

Table 14. Activities, obstacles and measures for decision-makers to stimulate demand side flexibility

Activities	Obstacles or lack of drivers	Measures
Energy tax on electricity, electricity certificates and VAT	Energy tax on electricity and electricity certificates skew the competitiveness of electricity compared to other input goods Energy tax on electricity and electricity certificates reduce the percentage price difference on the retail market	Review of the energy tax on electricity to meet the energy challenges of the future
Strategic reserve	The strategic reserve leads to customers not having to be flexible	With more flexible electricity use, the need for a strategic reserve reduces, and we therefore do not propose any measure
Investment support	Immature market The benefit to individual customers is lower than the benefit to the system Initial education costs[57]	Design investment support for control equipment of heating loads

Source: Ei

Review of the energy tax on electricity to meet the energy challenges of the future

Ei has established that the electricity tax affects the prerequisites for demand side flexibility, and has taken a first step by analysing some alternatives to the existing electricity tax. Ei proposes that the electricity tax is reviewed for the purpose of meeting future demands for more flexible electricity use.

The electricity tax is primarily a fiscal tax that disrupts the price signal to electricity users, as the electricity price no longer reflects society's real costs for production. A future with increased demand side flexibility assumes that electricity users become more sensitive to changes in the electricity price compared to today, and in this context, the cost of the electricity tax risks dampening price signals.

Design investment support for control equipment of heating loads

Ei proposes that the Government gives the Swedish Energy Agency the mandate to produce a proposal for investment support for control equipment of heating loads. The mandate could advantageously be carried out in collaboration with Ei.

The estimated potential of heating in the household sector is between 1 500 and 5 500 MW, see Table 3 in Chapter 2. This flexibility resource can create benefits at several levels in the electricity system. There may be several reasons why the technical potential to date has not been realised to any major extent. One important reason is that there are entry barriers, which means that consumers do not think it profitable to undertake measures to enable demand side flexibility. The cost of investing in the necessary control equipment in relation to the savings potential is one example of an entry barrier. The low level of knowledge about demand side flexibility is another. To utilise the potential probably requires a higher degree of automation, simplicity and other incentives than are available currently (Chalmers, 2014:b).

[57] This measure is addressed under Information measures in Chapter 3, Customer.

A subsidy might be suitable, as those who are "early adopters" otherwise have to pay a higher cost for being flexible, both in the form of equipment and information management, which hinders development. An example is a Swedish company where the cost of control equipment for a heat pump amounts to approximately 5 000 SEK. There is then a risk that both energy service companies and consumers delay the investment until the cost of the equipment and information management falls, and the market becomes more mature. This justifies the government initially subsidising customer investments in control equipment in order to speed up the development.

To minimise the administrative burden on customers, suppliers of control equipment could be the parties who apply for the support, and the deduction made direct in the customer invoices. The actors that Ei see as applicants are electricity service companies, who sell control equipment used in customers' existing plants. The actors can also be suppliers who choose to include control equipment in products sold, such as heat pumps.

for relevance, it could be mentioned that in 2006 Norway introduced investment support for load control equipment. The support is administered by Enova[58]. Equipment to facilitate control of household heating loads can receive support corresponding to 20 per cent of the overall investment cost, including VAT, or a maximum of 4 000 NOK. The support is paid to consumers who live in single-family dwellings or large-scale housing, can divide the housing into several heat zones and are able lower the indoor temperature for five hours or more[59].

When the regulations are adopted, it is important to simultaneously set up a goal for how much demand side flexibility shall be realised. To facilitate the goal, the subsidy should be conditional on at least two requirements. Firstly, the household's flexibility potential must be reported to the service hub (in accordance with the proposal for reporting to the service hub as described in Chapter 3). Secondly, the subsidy should be conditional on a minimum capacity for how much of the load can be controlled, for example over a 24-hour period or an hour. This will ensure that the means of control achieves the goal set, and that society's costs of financing the subsidy do not exceed the overall benefits that the increased demand side flexibility contributes to the electricity system.

Finally, there is a risk that the support has a cost-driving effect, that is to say the cost to the customer will be as high as before, and the difference becomes profit for the energy service company. This is important to bear in mind when the scope and duration of the support are finalised. The time during which the investment support is paid out should be limited to some years, and then be phased out.

[58] Enova is owned by the Norwegian government and works towards more environmentally friendly production and consumption of energy. This is done primarily through financial support and advice.
[59] https://www.enova.no/finansiering/privat/enovatilskuddet-/varmestyringssystem/912/0/

7 Costs and benefits of demand side flexibility

The socioeconomic benefits and costs of increased demand side flexibility are difficult to estimate and require many assumptions. In order to justify the implementation of the package of measures, society's benefits from the measures proposed by Ei must exceed the costs. For customers and market actors to start using demand side flexibility, they must also perceive that the benefit is greater than the cost of using demand side flexibility.

7.1 Proposed package of measures for increased demand side flexibility

The package of measures consists of the measures proposed and presented in Chapters 3–6 and summarised in Table 15. The table also indicates when each measure should be implemented to achieve increased demand side flexibility by 2030, and the order in which this should be done, although the timings are very uncertain.

Table 15. Proposed measures to achieve the action plan for increased demand side flexibility

Action plan	Measures	Time plan
Increase customer awareness of demand side flexibility	Customer-adapted information on demand side flexibility (information campaign and web portal)	Information campaign 2020–2022 when the subsidy for control equipment starts, and 2025 when the final measure is in place Web portal in place no later than 2025
	Hourly metering and access to hourly values for all customers	When the functional meter requirements are in place (no later than 2025)
	Create prerequisites in the service hub for voluntary reporting of flexibility potential	When the service hub is in place (no later than 2020)
	The Government should mandate the National Board of Housing, Building and Planning to include demand side flexibility potential in the energy declaration	Investigated further 2017–2018
	The Government should mandate the Swedish Energy Agency to:	
	- inform on demand side flexibility ahead of the energy mapping of large companies	Investigated further 2017–2018
	- inform on demand side flexibility when supporting energy mapping of small and medium-sized companies	Investigated further 2017–2018
	The Government should mandate the Swedish Energy Agency to produce a proposal for investment support for control equipment of heating loads	Investigated further 2017–2018

Action plan	Measures	Time plan
Promote demand side flexibility by giving customers information about options	Requirement for electricity network companies to inform customers about tariffs and other opportunities for cost savings	Enters into force 2017–2018
	Need for ongoing information from electricity retailers to customers about demand side flexibility	When Ei becomes entitled to issue instructions according to the proposed change[60] to Chapter 8, Section 17 of the Electricity Act
	Ei shall develop Elpriskollen to promote demand side flexibility through:	
	- reporting hourly price contracts on Elpriskollen	2017–2018
	- including network tariffs on Elpriskollen	2019–2020 (after instructions for tariff design)
	- creating a simulation tool on Elpriskollen to estimate customer saving potentials through selecting various offers	2021–2022 (after the service hub is in place)
	- undertaking measures to simplify sharing data from Elpriskollen with other actors who wish to develop smart services for customers	2021–2022 (after the development of Elpriskollen has been implemented)
Promote demand side flexibility by creating incentives for customers to offer their flexibility to actors	Ei evaluates the incentives in the electricity network regulations aimed at making efficient use of the electricity network	Investigated further 2017–2018
	Requirement for daily settlements per hour for all customers	When the functional meter requirements are in place (no later than 2025)
	Ei investigates whether compensation for network benefit can be given to actors other than producers, such as consumption plants	2017–2018
	Authorisation to Ei to develop instructions for network tariff design	2017
	Permit gradual introduction of new tariffs and pilot projects relating to tariffs	2017
	The Government should mandate the Swedish Energy Agency to:	
	- investigate how consumption bids can be promoted on the regulating power market	Investigated further 2017–2018
	- investigate how the prerequisites for automatic reserves from the consumer side can be promoted	Investigated further 2017–2018
	Ei works to enable products promoting demand side flexibility (enables load shifting) being offered by the electricity marketplaces	2017–2018
	Ei analyses and develops the aggregator role in line with upcoming European legislation and adapted to the Nordic electricity market	2017
	Review of the energy tax on electricity to meet the energy challenges of the future	

[60] Govt bill 2016/2017:13

7.2 Costs for certain measures for demand side flexibility

Ei has estimated society's costs and benefits from increased demand side flexibility. Customers' personal financial incentives have also been analysed[61]. We have chosen to estimate the costs of the measures that we assess as particularly costly but crucial for getting demand side flexibility going. The cost of measures that entail a change in legislation has also been estimated. The annual costs of these measures have been estimated to 769 SEK, plus a one-off cost of 21 million SEK, see Table 16. The resulting annual cost per customer is approximately 145 SEK.

The greatest cost relates to hourly metering and daily settlement per hour for all customers, and to investment support for control equipment. The cost of the investment support should be limited to some years, and cease when the market for control equipment has matured. The cost of hourly metering and hourly settlements can be expected to fall once the systems have been adapted to the transfer to daily offsetting per hour for all customers.

Table 16. Total costs of measures in the package of measures

Measure	One-off costs in million SEK	Annual cost in million SEK	Source
Investment support for control equipment of heating loads		200.5	Enova
Customer-adapted information on demand side flexibility	20		Swedish Consumer Agency, Swedish Energy Agency and Statistics Norway
Requirement for electricity network companies to inform customers about tariffs and other opportunities for cost savings		1	Ei
Hourly metering and daily settlement per hour for all customers		567	Sweco and Ei
Network tariffs in Elpriskollen	1.5	0.5	Ei
Permit gradual introduction of new tariffs and pilot projects relating to tariffs	0	0	Ei
Total cost	21.5	769	

The measures are proposed to be implemented over the period 2017 to 2025. To estimate the benefits, we started from the prerequisites on the electricity market in 2030, when the measures are expected to have increased demand side flexibility in Sweden. The benefits to society and to individual customers are estimated for a reference scenario representing a probable development of the electricity system in

[61]The detailed cost/benefit analysis to society and to customers presented in the original report is shown in a very summarised version in this section. The full analysis can be found in the Swedish concluding report *Åtgärder för ökad efterfrågeflexibilitet i det svenska elsystemet.*

Europe up until 2030. In this scenario, Sweden has 39 TWh of wind power, which is in line with the cross-party energy agreement[62], and 50 TWh of nuclear power.

7.3 Benefits of the package of measures

The benefits of the package of measures is difficult to estimate due to its dependence on the effect of the measures on demand side flexibility in Sweden. To calculate the benefit of the package of measures, we have estimated the benefits with an upper and a lower limit for the demand side flexibility to which the measures are expected to lead, see Table 17[63].

Based on the result of the analysis, Ei makes the assessment that the annual benefits of demand side flexibility in 2030 will be greater than the annual costs of the measures. This applies even if only half of the household customers choose to be flexible in their electricity use for heating.

Table 17 Estimated annual benefits of demand side flexibility for each typical problem (million SEK)

Typical problems or future challenges	Customers participating	Upper benefit estimate Potential within industry realised plus 100 per cent of household customers in single-family dwellings flexible in their electricity use for heating Annual saving (million SEK)	Lower benefit estimate Potential within industry realised plus 50 per cent of household customers in single-family dwellings flexible in their electricity use for heating Annual saving (million SEK)
Frequency regulation (automatic reserves)	Household customers	370	370
Power deficit situation	Industries and household customers	128	128
Inefficient use of resources	Industries and household customers	675	381
Local network problems	Household customers	587	294

Source: Ei

The benefits to society are greatest if demand side flexibility contributes to solving the challenges associated with inefficient use of resources and local network problems. These benefits can be realised through demand side flexibility entering into price formation on the day-ahead market, and through time-differentiated network tariffs to achieve a more efficient use of resources and use of the network. The grid in Europe is expected to be reinforced by 2030, which will result in fewer cases of electricity prices of 200 EUR per MWh during years with normal temperature winters. This means that the price levels required for power reductions within industry will be rare. The major benefit will instead arise through household customers' electricity use for heating being automated and directed towards price signals from electricity networks and/or retail. By moving their electricity consumption to another time, customers can contribute to more

[62] The cross-party energy agreement was reached between the Social Democratic Party, the Moderate Party, the Green Party, the Centre Party and the Christian Democrats in June 2016.
[63] The potential for demand side flexibility within the industrial sector and the household sector are shown in Table 3.

efficient use of resources in production, and more efficient use of the electricity network.

The customers, the producers of renewable production, and the electricity network companies will be the great winners from demand side flexibility. Energy service companies and other actors who help customers to realise the value of their demand side flexibility will also be winners as a result of greater demand for smart services and contracts. Demand side flexibility facilitates the integration of renewable electricity production through customers moving their electricity use to low price hours, when there is plenty of solar and wind power in the system. This means that these types of power can be used more than previously. The number of zero price hours will therefore fall, and the investment climate for wind and solar power production will improve.

Price peaks can be reduced, as household customers move their electricity use to low price hours. Our results show that when demand side flexibility enters into the price formation on the day-ahead market, the average annual price will rise marginally by 2030, which will favour producers with low marginal costs. The scenarios for 2030 are based on an electricity system with good transfer connections, resulting in fewer high price hours than there are low price hours. This means that the shifting of electricity use results in the "troughs" of the price curve being filled to a greater extent than the "peaks" are removed, and the average annual price increases.

Through their tariffs, electricity network companies can provide incentives to customers to be flexible in their electricity use to achieve more efficient use of the electricity network. The greatest savings for customers arise on the electricity network side, and it is therefore important that the network tariffs are designed to stimulate efficient use of the electricity network. In this way, customers can contribute to reducing network losses and investments in the network. As the electricity network operation is a regulated monopoly, cost savings for the network companies will in the longer term entail cost savings for customers. It is therefore important that the network companies have sufficient incentives in the electricity network regulations to use the potential for demand side flexibility instead of making traditional network investments, if this is a cost-effective alternative.

By improving the customers' prerequisites for being flexible in their electricity use, their position on the market is strengthened, as they can make more active choices and impact their own electricity cost more. Household customers' interest in electricity use is often very small, and for this reason electricity cost savings may remain a weak incentive for customers. Household customers do have other drivers, however. In the dialogue on demand side flexibility, it is important to highlight that customers can contribute to societal benefit through being flexible in their electricity use.

With the expected price levels for 2030, the investment in control equipment will be profitable to customers if the pay-back period is only a few years. Ei does, however, consider that investment support for controlling heating loads will be important. This is partly due to the low level of interest among customers of their electricity use, which is a threshold for new actors on the electricity market. It is also due to services for demand side flexibility being an immature market, where customers need to be informed about the societal benefit to which they can contribute, and the personal financial benefit they may receive.

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