MOWAT RESEARCH #138 | DECEMBER 2016

Future Drivers and Trends Affecting Energy Development in Ontario

LESSONS LEARNED FROM SWEDEN

Emerging Energy Trends

Mowat ENERGY

MOWAT'S ENERGY POLICY RESEARCH HUB

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Mowat Energy's *Emerging Energy Trends* is a comprehensive study of how technological and consumer disruptions in the energy sector could affect Ontario and beyond.

This paper is part of a series of background reports informing the final report. Initial funding for this research was in part provided by the Ministry of Energy of Ontario. The final report and all other background reports are available at mowatcentre.ca/emerging-energy-trends.

The Mowat Energy research hub provides independent, evidence-based research and analysis on systemic energy policy issues facing Ontario and Canada. With its strong relationship with the energy sector, Mowat Energy has provided thought leadership to stakeholders, decision-makers and the public to help advance discussions on the challenges that energy is facing in Ontario.

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This paper produced by Sweco.

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DECEMBER 2016
 ISBN 978-1-77259-026-5

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Report name	Future Drivers and Trends Affecting Energy Development in Ontario
Availability status	Public
Completion date	20160426
Project manager	Len Börjeson
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1 Summary

Distributed Energy Resources (DER) has become a significant topic when discussing the power sector of the future. A full scale implementation of DER would have a large impact on the power sector: on current rules and regulation, retail competition, and the business models of leading centralized generators as well as other incumbents.

A change of attitude towards energy is currently taking place. In parallel with people complaining over conservative utilities and rising energy costs (especially grid costs), new energy technologies – especially DER – are perceived as something interesting and even cool. General public interest towards green technologies and environment remains and is likely to continue being strong in the future. The issue of branding and especially public opinions will become increasingly important, particularly with the development of DER technologies. The household customers, and to some extent the commercial sector, are increasing their installations of DER. Altogether, these factors can affect not only the consumers' choice to install DER, but also affect decisions of policy makers. There are strong political incentives in Sweden today to invest in DER such as PVs EVs and other DER. As an example, installations in PVs receives both investment support (20-30%) and tax reductions between 40-60 öre/kWh. Installed DER grows rapidly, yet from very low levels.

It is obvious that the implementation of DER fits hand in hand with the implementation of smart grids, smart homes and smart appliances. It could be argued that these topics are two sides of the same coin. Advanced metering and the development of new IT-applications – including big data analysis – are integral parts of this development. It can therefore be assumed that these aspects will contribute to a swifter change of the sector compared to what usually has been the case.

However, the opinions about DERs future role in Sweden vary widely. Some claim it is a temporary trend that will be marginalized, and others claim that the utilities will have to see themselves defeated by DER as the future major energy resource. This is reflected in the current debate about the future of nuclear power in Sweden – should this power source be left to its destiny (low energy prices and high taxes) and decommissioned or should it receive financial support.

Increased DER brings on some challenges to the current system: intermittent production, need for increased grid capacity, potential reversed flows as well as potential stranded assets. Sweden has not yet seen any large-scale effect of customers disconnecting from the grid or heavily reducing their outtake. There are however some experience of this type of diminishing returns in Sweden, mainly within the district heating sector. Regulation and tariff design creating the right incentives for both energy companies and energy users will continue to be of uttermost importance and we expect a shift toward more capacity charges and an increase in design complexity. Apart from the challenges increased DER also presents several opportunities including reduced grid losses due to electricity generation closer to load, increased renewables as well as possibility for DER to help balancing the system, especially DR. There is still a large improvement potential for increased demand flexibility using DER.

Some of the main lessons learned from the Swedish electricity market are:

- The retail market deregulation has enabled energy users to choose electricity suppliers. The many different suppliers to choose from in combination with multiple services to compare possible electricity contracts (provided both by authorities and by private companies) have led to a more transparent competition at the retails' end and thus led to lower retail prices.
- The regulated (monopoly) part of the electricity market are in question, primarily due to the DSOs relatively high prices. This is partly explained by the regulation design, allowing relatively high revenue caps.
- The tariffs set by DSOs and electricity suppliers (retailers) sometimes create conflicting incentives. Energy users in Sweden today have two separate contracts: one with an electricity supplier and one with a DSO. These set their tariffs in order to distribute costs, but also to an increasing extent to create incentives for the energy customers to shift their load (demand response). DSOs set their tariffs to create incentives to reduce grid losses and peak loads (at local level), whilst electricity suppliers set their tariffs according to spot prices (electricity system level). Hence, the sometimes conflicting tariffs' incentives disturb price signals for electricity users to carry out the demand response.
- Today, customer focus has become a top focus for Swedish utilities. The utilities see how the market is changing and how "the new energy customer" has different expectations towards their energy companies than before. It has recently been confirmed that sustainability and customer focus (satisfaction, involvement of consumers) dominated discussions of Swedish energy companies (producers, distributers, traders of electricity, heating and cooling) while developing a common vision for 2050.
- Sweden has identified the need for a central data hub and the decision has been taken to implement one. The electricity market users' data – such as electricity consumption data – was previously stored locally by each DSO (approximately 170 DSOs in Sweden). Given the deregulated market, power suppliers (approximately 120) and other stakeholders needed to get their data from this large number of DSOs. The hub will be an access point for the competitive stakeholders to the electricity market. The data hub is currently being developed and is expected to be operating from the last quarter of 2020.
- Sweden was early to introduce smart meters. This has resulted in large amounts of electricity user data. With large volumes of data, there is a significant opportunity to perform so called big data analyses. These enable an understanding of cost distribution among customer groups. Big data analyses can also extract aggregated trends combined with analyses of individual customer's behavior, combined with external data such as weather and economics. Big data analyses are currently being used in Sweden for the analysis of new tariff designs and for identifying grid losses and their locations.
- The energy only market combined with electricity certificate system can be said to have created incentives for additional VRES (Variable Renewable Energy Sources), including intermittent wind- and solar power, rather than generation with higher availability. The issue of capacity has thus become an increasingly important topic in Sweden.
- Even if small-scale renewable production in Sweden has a lot of financial incentives, many stakeholders argue that there are too many different support schemes and exemptions, that it is too complex to be considered as a genuine support mechanism by potential micro producers, especially taking into account the extensive application processes. Some also argue that the current system does not send the right signals: for example, the tax savings

are paid back from feeding-in renewable to the grid only once a year, rather than continuously.

- In recent years, a strong trend for heat pumps has been seen, including both air based and geothermal heat pumps. The growth in heat pumps usage has been especially strong in the stand-alone residential houses (villas) segment. The growth was particularly strong around 10-15 years ago when oil heating, bio fuel heating and direct electrical heating was replaced by heat pump systems. A slight slowdown in sales of heat pumps has occurred in recent years, while the proportion of single-family homes that are heated by direct electricity or oil is very small. Moreover, driven by technological development and currently low electricity prices, heat pumps are now to a larger extent also competing with existing district heating systems in segments such as district heating connected villas, multiple-family houses and commercial buildings etc. The heat pumps have by fact led to demands for more capacity in certain electricity distribution networks, but these requirements already exist today and the additional change to the year of 2037 is considered small.

2 Background

The Mowat Centre is an independent public policy think tank located at the School of Public Policy & Governance at the University of Toronto and Ontario's non-partisan, evidence-based voice on public policy. Mowat undertakes collaborative applied policy research, proposes innovative research-driven recommendations, and engages in public dialogue on Canada's most important national issues. Policy areas of expertise are intergovernmental economic and social policy, state transformation, energy policy and not-for-profit policy.

The Mowat Energy research hub provides independent, evidence-based research and analysis on systemic energy policy issues facing Ontario and Canada. With its strong relationship with the energy sector, Mowat Energy has provided thought leadership to stakeholders, decision-makers and the public to help advance discussions on the challenges that energy is facing in Ontario.

Mowat Energy is conducting a comprehensive study of emerging trends facing the energy sector, with a focus on the drivers and potential trajectories of energy transformation in Ontario and on the effects of energy transformation on Ontario's energy sector and beyond. The purpose of the study is to produce short-, medium- and long-term recommendations to help the sector, policymakers and regulators better prepare for Ontario's possible energy futures.

Mowat Energy has engaged the Energy Markets department of the Swedish consultant Sweco to compile the results from relevant studies in Sweden and the Nordic countries. These results are presented in accordance with four specifically defined topics presented in the following sections. This synthesis is primarily based on roughly 20 reports that Sweco have drafted over the last 4-5 years.

3 Methodology

With reference to the assumptions mentioned in subchapter 3.1 the study will largely comply with the proposed scope of the RFP. The results will be presented as four distinctly separate reports (chapters 5 to 8). After a review of our findings to date we propose to deliver portfolio 1 and 4 in a somewhat more condensed form compared to portfolio 2 and 3.

The assignment will be performed in two phases as requested:

Phase 1)

A rough synthesis will be developed. The synthesis will primarily include structured abstracts from previous work as well as certain modifications based on the specific conditions in Ontario. It is foreseen that roughly half the proposed budget will be used for phase 1.

This rough synthesis will be based on the following activities:

1) Initial discussion (phone conference) to gain additional insight of Mowat's project objectives
2) Selection of previous work and reports that are relevant for the assignment
3) Translation to English when applicable
4) Structure findings in line with the four proposed portfolios

The initial phone conference is extremely important, as this call will lead to a more thorough understanding of project expectations and project deliverables.

Phase 2)

Based on comments from Mowat, the synthesis will be further clarified. It is foreseen that the work will focus on establishing a sufficient consolidation of the synthesis as well as providing further clarification on specific aspects of the reports. It is assumed that this information will be attained from the public domain, expert contacts and the team's experience from relevant past assignments.

3.1 General Comments and Assumptions

Results and findings are primarily based on Swedish and Nordic experiences. In order to understand the background for the energy sector development as well as the rational for decisions made, both by the government as well as sector stakeholders, significant effort has been made to capture the specific market conditions of the Nordic region.

Although the development over the last 10-15 years have been driven by the introduction of RES (Renewable Energy Sources) and related support mechanisms for RES, the primary emphasis of this report has been made to capture how DER affects various system aspects. Issues related to RES have been presented and discussed when these topics have been related to DER.

3.2 List of Acronyms

The following acronyms were widely used in the current report

ACER	The Agency for the Cooperation of Energy Regulators
BRP	Balance Responsible Party
CAPEX	Capital Expenditure
CEMI	Customer Experiencing Multiple Interruptions: the proportion of customers (power outtake points) which has four or more unannounced power outages (between 3 minutes and 12 hours) during a year
CHP	Combined Heat and Power
Prosumers	Consumers with own generation
DAM	Day-ahead market
DR	Demand Response
DER	Distributed Energy Resources
DSO	Distribution System Operator
DSM	Demand side management
ELFORSK	Swedish Electricity Research Centre (changed to ENERGIFORSK Swedish Energy Research Centre
ENTSO-E	European network of transmission system operators for electricity
EV	Electrical Vehicle
FCR-N	Frequency Containment Reserve for normal operating band
FCR-D	Frequency Containment Reserve for disturbances
FRR-A	Automatic Frequency Restoration Reserves
FRR-M	Manual Frequency Restoration Reserves
GEODE	Organization of independent European distribution companies of gas and electricity
GP	The Green Policy scenario as defined by the organization NEPP
ISP	Imbalance Settlement Period
LCOE	Levelized cost of electricity
NEPP	North European Power Perspectives
Nord-REG	Organization of the Nordic energy regulators
O&M	Operation and maintenance costs

OPEX	Operational Expenditure
PV	Photo voltaic electricity generation
RES	Renewable Energy Sources
RSO	Regional system operator
SAIDI	System Average Interruption Duration Index: average interruption time for unannounced and announced power outages per customer type.
SAIFI	System Average Interruption Frequency Index: average interruption frequency for unannounced and announced power outages per customer type
SCADA	Supervisory Control And Data Acquisition
SE1-4	Spot market price areas for electricity in Sweden (1 is in the most northern part of the country and 4 is situated in the south)
SvK	Svk, Swedish TSO
TOTEX	Total Expenditure
ToU	Time-of-Use tariff
TSO	Transmission System Operator
VRES	Variable Renewable Energy Sources
WTP	Willingness-to-pay
Öre	1% of SEK, 1 SEK = 0.158 CAD (in May 2016)

3.3 Outline of the report

The outline of the report with short descriptions of contents can be viewed in Figure 3-1 overleaf.

Figure 3-1: Outline of the report

(1) Summary and (2) Background

The chapter Summary provides a summary of the study's main findings. The Background includes a short description of the study.

(3) Methodology

These chapters provide a list of acronyms used in the report, describe the used methodology as well as provide some general comments and assumptions used in the study.

(4) Market design

Outlines the Swedish electricity market: its structure, price formation etc. It focuses on the electricity market as it is today, but also shows some of the energy sectors development over years – achievement of the Swedish energy policy.

(5) The New Energy Customer

Describes current trends and drivers of different electricity consumer's in Sweden. It describes how and why changes are occurring and to which customer groups. It also presents lessons learned and the expected development further.

(6) Meeting Energy Demand Behind the Meter

Describes current DER development and incentives behind it for different customer groups. It also presents lessons learned from how incentives are designed and which effect this has had on the energy system. The chapter also includes price areas and the role of regional planning, as well as future development regarding DER and its challenges and the services.

(7) Grid modernization and the utility of the future

Presents the grid system view: how DER affect DSO and TSO. It describes the grid regulation, the DSOs incentives, their revenue model, challenges, tariff design etc.. It also describes their obligations towards the electricity consumers (for example grid reliability), the possibilities data and meter information can bring, and how DER can be part of demand flexibility.

(8) The future of Centralized Supply

Describes Sweden's large scale electricity generation and its future. The Chapter also includes capacity reserves and how this can be used as well as an assessment of the future of energy storage at transmission grid level. It also examines future possible business models and ways for large scale generation to remunerate.

4 Market Design

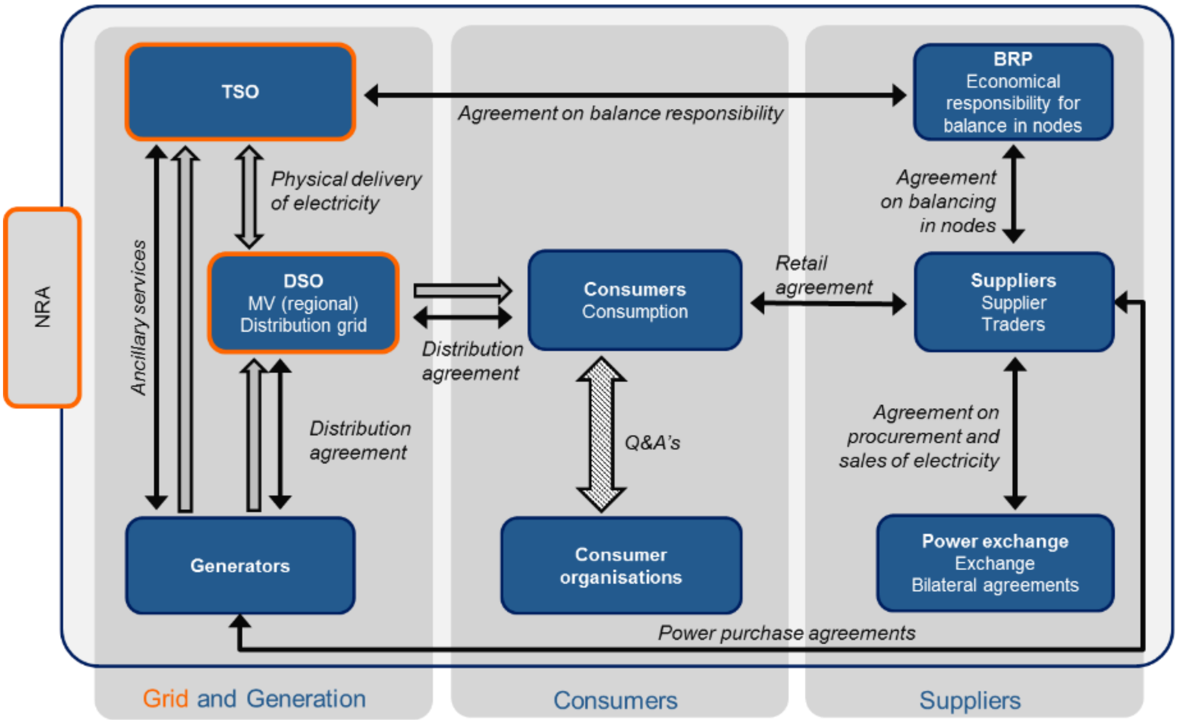
In Sweden, the power market is generally deregulated – apart from its natural monopolies (grids), the price is set by the supply-demand curve. Supply and demand side companies provide their bids for every hour of the next day, and a sophisticated automatic calculation determines the price based on the received bids. The market clearing price becomes the unified hourly price for the bidding zone.

This fundamental structure and further details described in this chapter provide a background to the environment which affects most, if not all, decisions in the sector.

4.1 Conceptual Description

Table 4-1 presents a brief description of the electricity market design in Sweden. Figure 4-1 shows a schematic overview of the Swedish electricity market, with its roles and relations. Black arrows indicate contractual agreements and grey arrows indicate physical flow of electricity. The regulated parts of the market (TSO and DSO, as well as the regulator itself) are marked with orange. The rest of the market is overall deregulated and competitive.

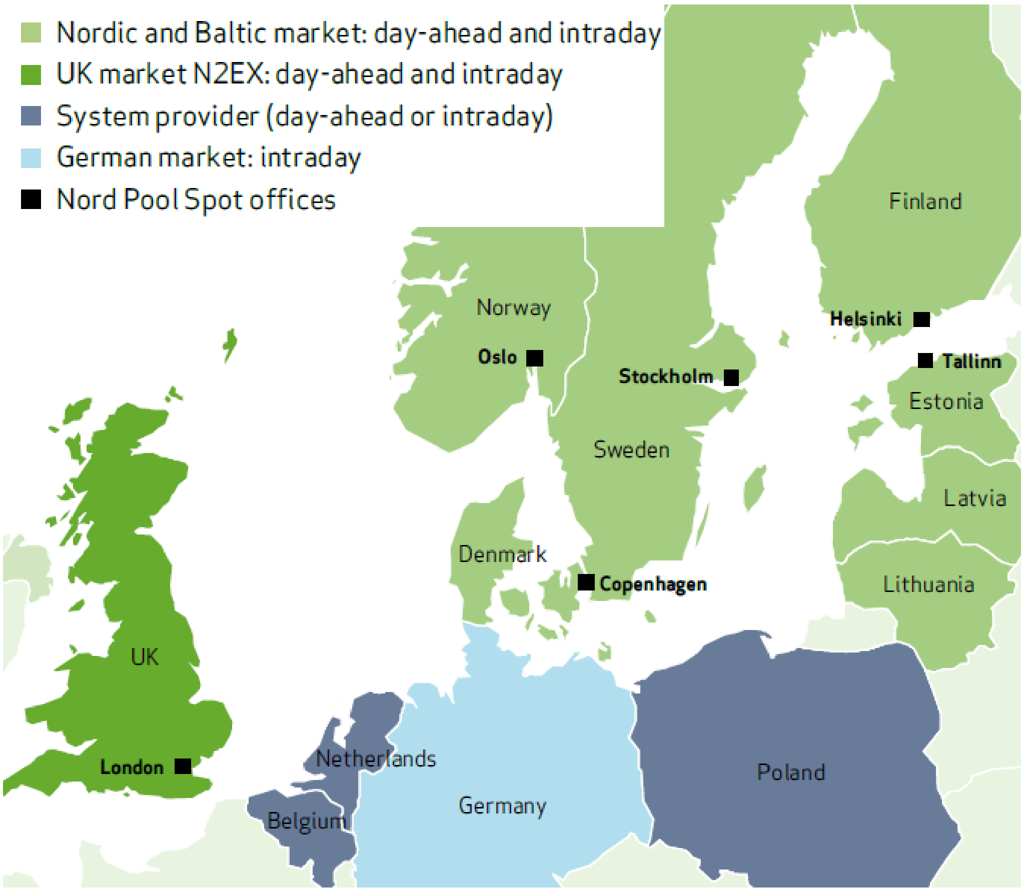
Figure 4-1: Power market roles and relations in Sweden.



Source: Svensk elmarknadshandbok, translated and modified by Sweco

Table 4-1: Overview of Sweden's electricity market

General	In the transport sector, the energy use was in total 85 TWh in 2014. The sector uses mainly diesel and petrol (71 TWh), even though bio fuels (11 TWh) and electric vehicles (3 TWh, including trains) are growing. This is the sector where de-carbonization presents the largest challenge. The households and service sector used 140 TWh in 2014, mainly comprised of electricity (68 TWh, mainly in terms of heat pumps) and district heating (45 TWh). The industry sector used 143 TWh in 2014, out of which biofuels (56 TWh) and electricity (50 TWh) were the most common used energy-types. In Sweden electricity is the dominating energy, whilst natural gas is only used to some extent (9 TWh, in the south of Sweden connected to the Danish grid). Hence, the main focus in this table is on electricity.
Market model	Sweden's market design is an "energy only"-market, meaning that electricity producers only gets payed for the hours when they generate power. This is then supposed to cover all the cost associated with their electricity generation business. Some countries in Europe has introduced capacity markets, where electricity producers are paid due to the capacity they provide, and there are stakeholders in Sweden who are arguing for a transition towards more capacity-based mechanism. The main part of physical electricity is traded through the market space Nord Pool while the financial trading to a large extent takes place on Nasdaq. A total of 380 members are active at Nord Pool Spot across nine countries.

Power Market	**Geography and key figures**	Sweden, Norway, Denmark, Finland, Estonia, Latvia and Lithuania; Partial services in the UK, Germany, Poland, Netherlands and Belgium; Total traded volume in 2014: 501 TWh  *Source: Nord Pool annual report 2014 modified by Sweco*

Power Market

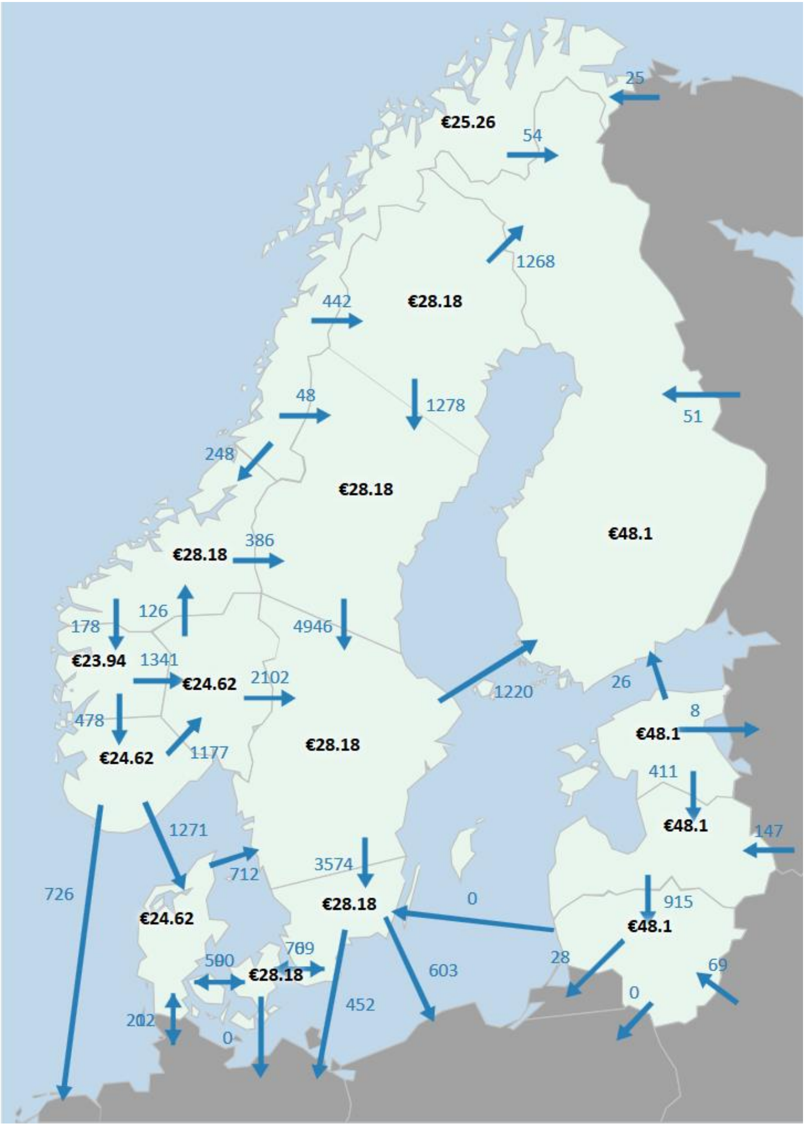
Day-ahead market

Nord Pool is the main area for the physical trading of electricity and it is driven by planning. Power buyers and sellers (in volume of demand/delivery and price) submit their bids for each hour of the coming day.

Based on supply, demand and transmission capacities the market clearing price is then calculated. The price represents both cost of electricity production from the most expensive source needed to be employed in order to balance the system, and the price that the consumer group is willing to pay to satisfy its demand. All electricity producers are then payed the clearing price (marginal pricing market).

In order to relieve congestion of transmission capacities, about 15 bidding zones have been introduced. The zones have own electricity prices that can be quite different among the bidding zones.

During 2015 489 TWh was traded. Average price for the Nordic in 2015 was 21 EUR/MWh. Prices are historically low and utilities are have been forced to do large write-downs.



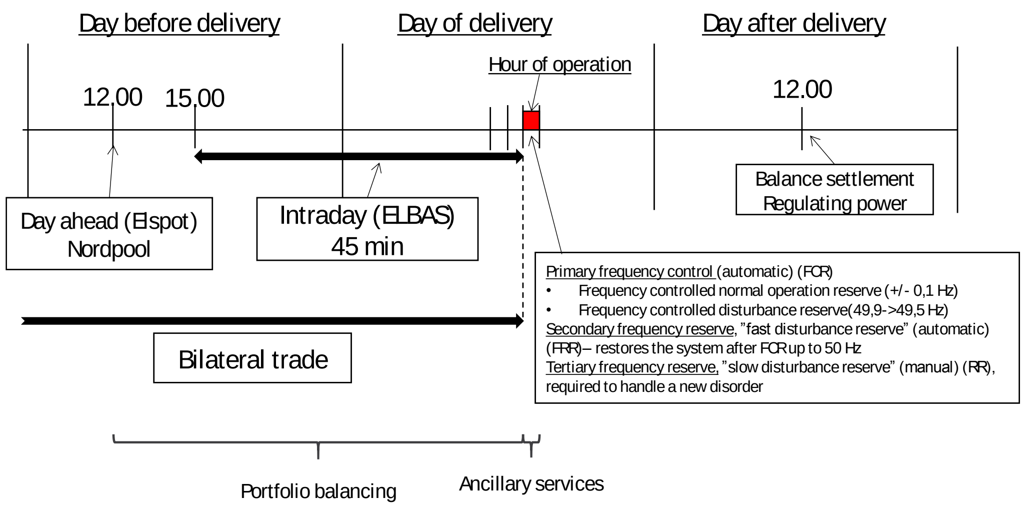
Source: Svk, accessed on www.svk.se at 9:00 on May 30, 2016

Power Market

Intraday market

The intraday market supplements the day-ahead market to secure the balance between power supply and demand. The market becomes increasingly important with larger intermittent sources entering the market.

Trading takes place every day 24/7 until one hour before the delivery. Capacities available for intraday trading all 24 hours of the following day are published. The prices are set based on a first-come-first-served principle, where best prices come first – highest buy price and lowest sell price.

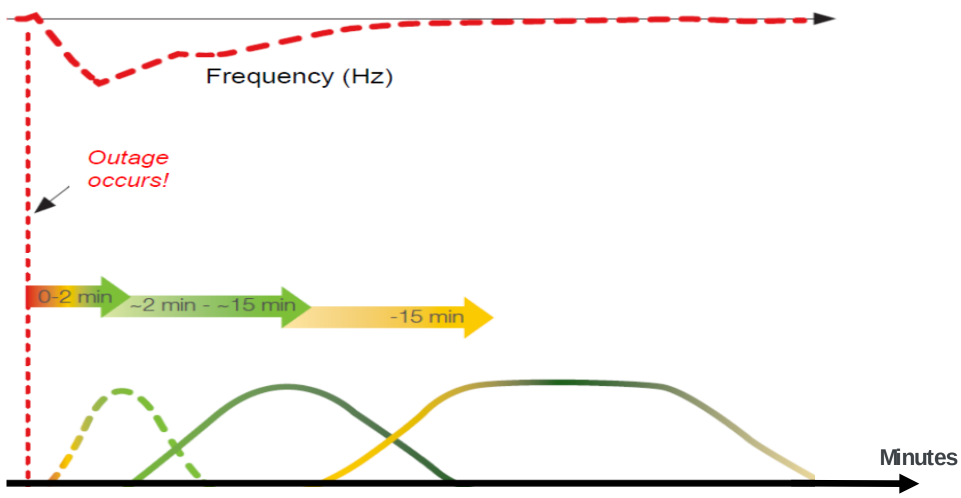


Source: Svk modified by Sweco

Balancing market

Market operated by national TSOs to maintain the power balance.

Simplified it can be said that the TSO procures the automatic primary (FCR-N and FCR-D) and secondary (FRR-A, under development) frequency control in advance whilst tertiary frequency control (FRR-M) is called off after bids with short notice (often within an hour). Hydro power is the dominant balancing (frequency control) resource used today.

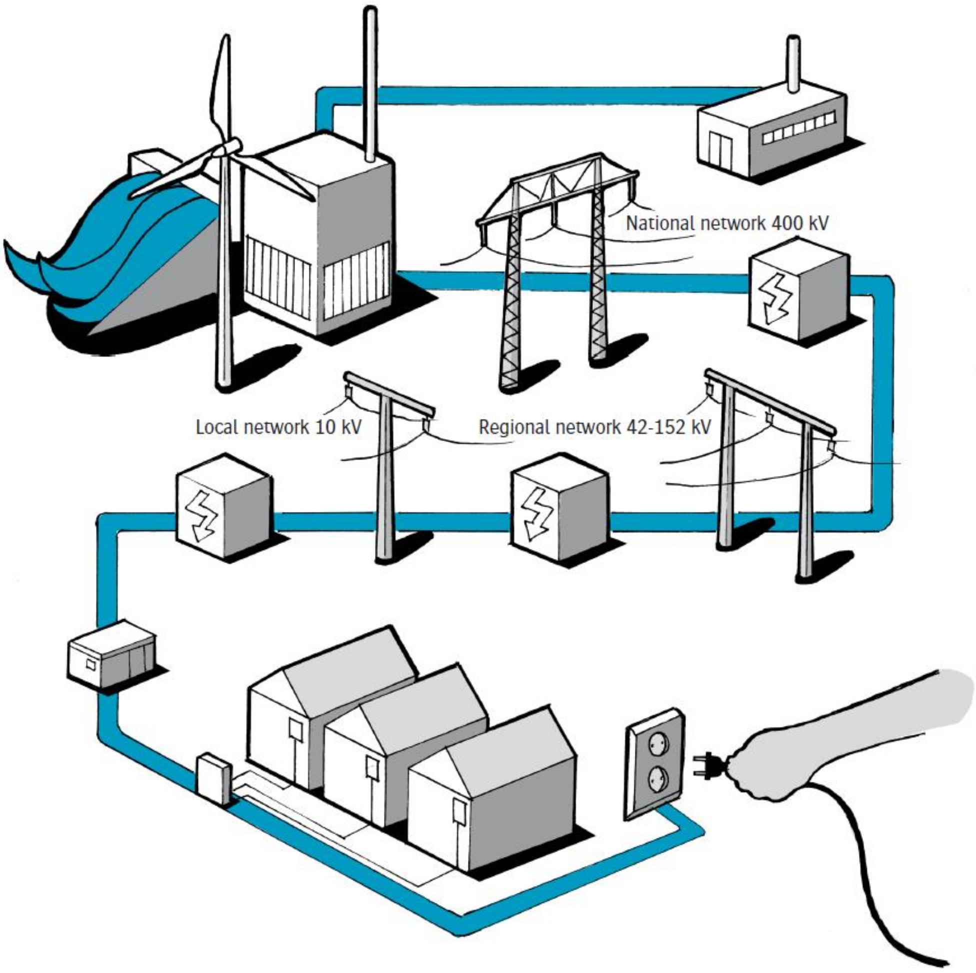


Source: Sweco

	Cross-border markets	There is an ongoing work in EU to integrate the European power markets – both physical integration through interconnectors and market integration. The EU process of harmonizing European power markets aims to improve efficient use of energy across national borders, implying among other market coupling and continuous intraday trading (XBID Market Project). Nord Pool together with three other Power Exchanges and 13 TSOs successfully launched the North-Western Europe (NWE) day-ahead price coupling project in February 2014. Day-ahead Price Coupling of Regions (PCR) is based on a single algorithm, robust operation and individual power exchange accountability.
Power Market	Financial market	Financial contracts traded through the Nasdaq Commodities are used for price hedging and risk management. The contracts have a time horizon up to six years, covering daily, weekly, monthly, quarterly and annual contracts. The calculated price for Nordic region disregarding bottle-necks in the system is used as a reference price. There is no physical delivery for the contracts, and technical conditions (capacity, grid congestion) are not considered. The traders can manage risks associated to the physical market prices with financial (forward) power market. Trading products are futures or forwards.
Bilateral contracts		The main part of the trade is through Nord Pool (physical electricity trade, Elspot day-ahead) and Nasdaq (trading of financial contracts). However, bilateral contracts are also possible. It is common for especially energy intensive industries to hedge some of their usage through long-term contracts.
RES-support mechanisms	Market-based mechanisms	**1. Green electricity certificates** The Swedish-Norwegian system aims at increase of power production from renewable energy sources in a cost-effective manner. Producers from renewables or peat receive 1 certificate for 1 MWh power produced the first 15 years in operation. They are free to sell certificates. Power suppliers and large consumers are obliged by law to supply/use certain quota of renewable energy that they secure by purchasing the certificates. Electricity certificates have market based prizing and this varies over time due to quota, supply of renewable electricity and electricity demand The quota is set by the government and is 21.3% for 2016. Certificates trading occurs at the electricity certificates market. Electricity certificates are mainly traded in two types of contract: spot price contracts and forward contracts. There are penalties for not fulfilling the quota obligations. The certificate price which the producer gets paid is currently about 16 EUR/MWh. The electricity suppliers cost averaged 2.1 EUR/MWh 2015. **2. EU Emission Trading Scheme** Covers 28 EU countries + Iceland, Liechtenstein and Norway. Covers 45% of EU's GHG emissions. The EU ETS works on the 'cap and trade' principle: volume of greenhouse gases that can be emitted each year is a subject to cap set at EU level; the companies receive or buy emission allowances which they can trade if they wish. From 2013 the cap is reduced by 1.74% each year. After 2020 this is proposed to be reduced by 2.2% yearly. Swedish companies which are part of the EU-ETS system are not obligated to pay Swedish CO2 tax.

	Other	Energy users and energy producers pay different energy taxes. Energy producers pay the following taxes: • Property tax • Capacity tax (only nuclear) • Taxes and fees on fossil fuels and emissions (energy tax, CO2 tax, Sulphur tax and NOx-fee) • Energy users pay energy tax on electricity and fuels and the above mentioned taxes and fees on fossil fuels. There are additional support systems for renewables and DER. These are described in Chapter 6.1.4.
Generation	**Fossil**	Fossil fuel based electricity generation pays property tax, emission allowances as well as Sulphur tax and NOx fee (plus energy tax and CO2 tax for a small part of their production). In 2013, Swedish power generation from fossil sources was 1.6% of total power generated.[1]
	Hydro	Hydro power mainly pays property tax, which is much higher for hydro than for any other energy type. In 2014, the Swedish hydropower generation was 63.3 TWh, accounting for 42% of total generated power.
	Biofuels	Bio fuel pays property tax and NOx fee. It can receive electricity certificates. In 2014, the Swedish CHP generation (mainly biofuel) was 13 TWh, accounting for approximately 9% of total generated power.
	Waste	The use of waste in CPH has increased in Sweden. The statistics does not specify waste as a specific district heating fuel category, but it is one of the main contributors to “biofuels” (62%, about 36TWh) and “other fuels” (12.1%, approximately 7 TWh) in the district heating fuel statistics. The main reason for the increased use of waste is the income from receiving the waste, which comes from the relatively high tax on waste deposit (500 SEK/ton) which otherwise needs to be paid. Waste fueled CHP pays emission allowances and NOx-fee (however the NOx-emissions are low do it is a net income for waste CHP).
	Nuclear	Nuclear power pays nuclear tax and property tax. In 2014, the Swedish nuclear generation was 62.2 TWh, accounting 41% of total generated power.
	Intermittent RES	Different subsidies are in place for renewables. • Investment Aid for solar PV • Reduced tax for micro produced renewable power (net users) • Conditional commercial Loans to start-up RE companies; • Conditional commercial Loans to connect RES • Reduced feed-in tariff for small scale electricity production Wind power account for the largest part of installed intermittent RES. In 2014, the Swedish generation of wind was 11.2 TWh, accounting for 7.5% of total generated power.

[1] http://www.ekonomifakta.se/Fakta/Energi/Energibalans-internationellt/Elproduktion-med-fossila-branslen/

	Overview of electricity network	 *Source: Energy Market Inspectorate*
Transmission	**TSO**	The Swedish national grid is a regulated national monopoly, operated by the Swedish TSO Svk. Svk is a non-commercial organization, neutral and independent towards the market members. In the Nordic countries, the system operators have the responsibility for both the security of supply and the high-voltage grid transmission grid.
Power distribution	**Power Suppliers**	In Sweden the power supply is a competitive market with around about 120 power supplying companies in Sweden. Power suppliers have balance responsibility (or outsource this to another agency/supplier), meaning that they have a financial responsibility to ensure that there is always a balance in the amount of electricity added and withdrawn at the infeed and outtake points that fall under the balance responsibility. The electricity supplier must by law be a separate company than the electricity producer and the distributor of electricity (legally unbundled). However, they can be within the same company group and have the same owner. The power suppliers purchase the electricity from the producers or from the market, and sell it to end users. The role involves having commercial contacts with the end users. The suppliers are obliged by law to a quota of renewable energy supplied. There are approximately 25 balancing responsible parties in Sweden. Out of these some are also electricity suppliers (for example Vattenfall) and some only provide balancing responsibilities to other electricity suppliers.

<table>
<tr><td></td><td>Distribution grids</td><td>

The distributions grids are regulated regional monopolies.

The regional transmission networks transport electricity from the national grid to the local networks (DSOs), in some cases also to major users, such as large industrial companies. There are approximately 170 DSOs in Sweden. The three largest ones (Vattenfall, E.ON and Ellevio) have slightly below 3 million out of a total 5.5 million grid connections.

The grid operators own regional and local networks. All electricity network operators must have a permit (known as a concession) to construct power supply lines. The Energy Markets Inspectorate issues these permits after an assessment. They are responsible for ensuring the power is delivered to the users. Each grid owner has a revenue cap.

The Energy Markets Inspectorate evaluates the equity of the total revenue that the network operators may charge their customers.

Indicative numbers for DSO costs can be seen in Table 4-2. Especially note the trend of the shares being halved for each cost type (1/1, 1/2, 1/4, 1/8).

Table 4-2: Indicative numbers for the DSOs costs (nation-wide)

Type	Share [%]
CAPEX	53,3
Feeding grid subscription	26,6
ADMIN	13,3
OPEX	6,6

Source: Sweco

</td></tr>
<tr><td>End consumers</td><td>Commodity price structure</td><td>

Electricity consumers in Sweden are free to select among about 120 power supplying companies.

The consumer pays both a grid fee and an electricity supply cost, meaning that the user in most cases gets two separate bills. The grid fee paid to the grid operator normally consists of a fixed cost based on their fuse size (in other words based on the maximum power use) along with a variable transmission fee (SEK/kWh).

Electricity consumers also pays tax and VAT on their electricity bill. The tax is around 0.3 SEK/kWh (not including VAT).

</td></tr>
<tr><td>Authorities</td><td>Policy</td><td>

The Ministry of the Environment and Energy (part of Government Offices of Sweden) is responsible for the Government's environmental, energy and climate policy. Each department at the Government Offices of Sweden has government agencies to enforce the law and carry out the activities parliament and the government has decided on, the Swedish Energy Agency being the most central one within the area of energy.

Swedish Energy Agency is a governmental authority that works on efficient and sustainable energy consumption as well as a cost-efficient and secure Swedish energy supply. The agency comes under the Ministry of the Environment and Energy.

The Agency works on related analysis, market development questions and R&D. The Agency is responsible for administrating several policy instruments.

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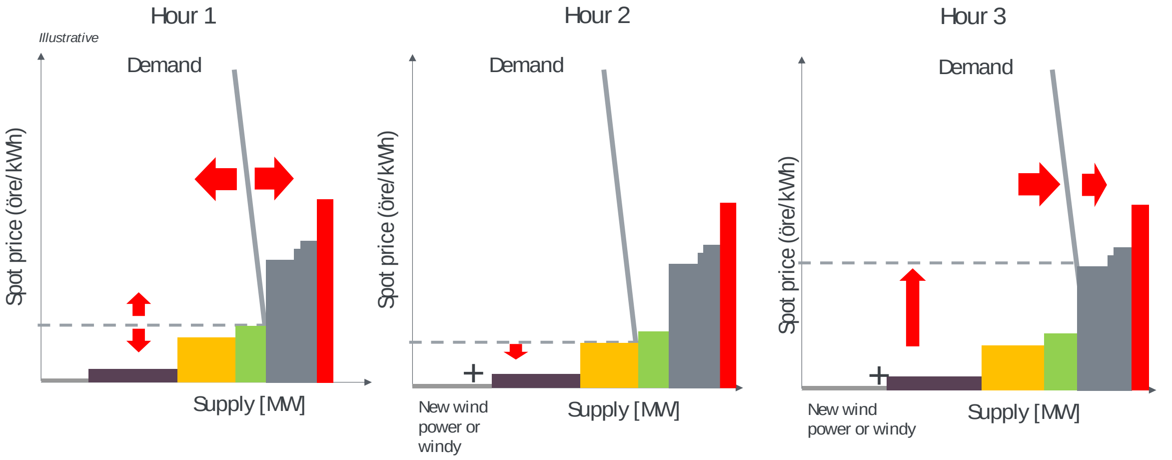
</table>

	Regulation	**Swedish Energy Markets Inspectorate** (Ei) is the supervisory authority for the electricity, natural gas and district heating energy markets. It checks that energy companies follow the regulations, works to ensure that energy markets function well, and monitors grids monopolies. Ei monitors that the electricity and gas network fees are reasonable, objective and non-discriminatory. Ex ante regulation of electricity network fees was introduced in 2012. This means that every electricity grid operator has been given a revenue cap for the total amount that they may charge their customers during the years 2012-2015. The purpose of the revenue caps is that companies shall obtain reasonable coverage for their costs and reasonable return on the capital that is required to run the operation. At the same time, the regulation is designed to ensure that the electricity customers shall have sustainable and stable fees.

4.2 Price formation

Sweden’s electricity spot price is set through marginal pricing each hour.

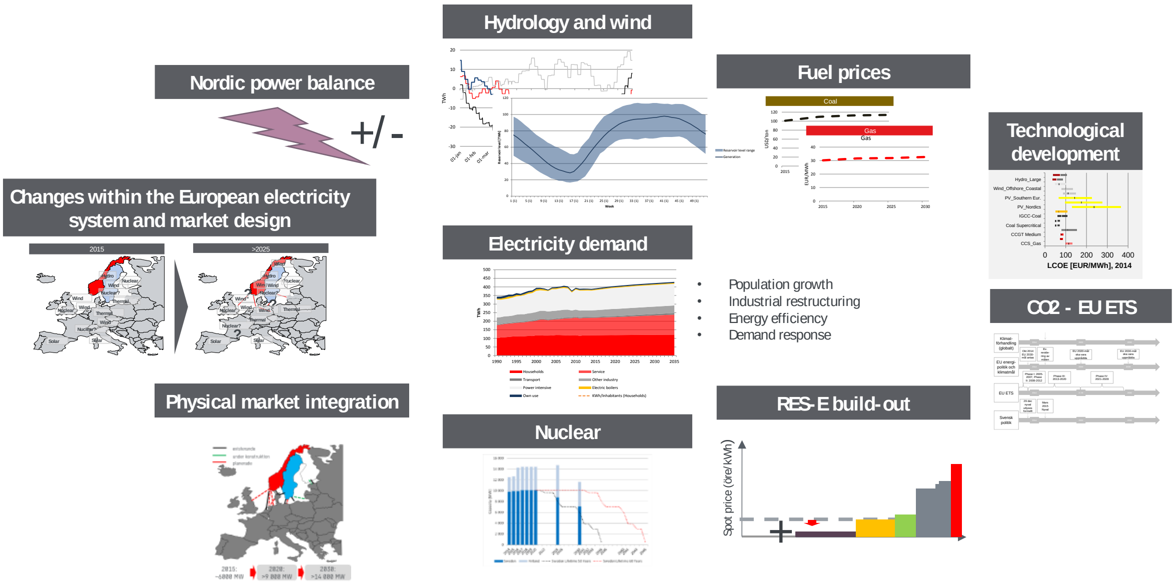
Figure 4-2: Price formation in Sweden



Source: Sweco

There are many factors influencing the spot price, such as the price of carbon, EU emission allowances, demand and the level of renewable generation. Renewable generation has zero or very low marginal pricing, thus shifting the merit order and decreasing prices. Sweden being interconnected to the continent however means that the price of coal, gas and EU emission allowances still have a large effect – even if Sweden mainly has generation with low marginal pricing (hydro and nuclear power).

Figure 4-3: Factors influencing the development of power prices – and the perception of these change over time



Source: Sweco

Sweden is since November 2011 divided into four different price areas. The areas were decided based on assessments on where it would be appropriate to make (simplified) price areas borders based on physical transmission capacity limitations. The principle is that the prices in each area are set based on production and demand as well as the capacity which can be transmitted between areas. The price setting of the spot price in each price area is market based but there exists both a ceiling (3000 EUR/MWh) and a floor price (-500 EUR/MWh). The transmission capacity between the Swedish price areas are good and most of the time the prices are exactly the same in all price areas. During 2015 all price areas in Sweden had the same price during 86 percent of the hours. The average prices during a year is approximately the same in all four price areas.

During hours of is grid congestions, the price differs between the price areas. Overall, the power prices are lowest in the North of Sweden where there is large hydro generation and highest in the South of Sweden were most demand is.

The price areas were introduced since neighboring countries (mainly Denmark) demanded it in order to better reflect the actual prices (and create the right price signals) in different geographical areas. Before the price areas were introduced, the South of Sweden during some hours had an artificially "too low" price since it had the average price for all of Sweden. During these hours the North of Sweden instead had a slightly "too high" power prices. Denmark overall has higher power prices than Sweden. Since Denmark is located just south of Sweden, the price difference during these hours was "artificially larger" than it should be if the transmission limitations were correctly mirrored. The EU is working towards creating an internal European power market. EU has legislation saying that there should be no internal market borders in Europe and that it against EU rules to give foreign companies disadvantages. Denmark therefore made complains to the EU regarding the price areas, which resulted in the introduction of the price areas. Denmark has two different price areas and Norway five.

Table 4-3: Average yearly prices for different price areas in Sweden during the last four years

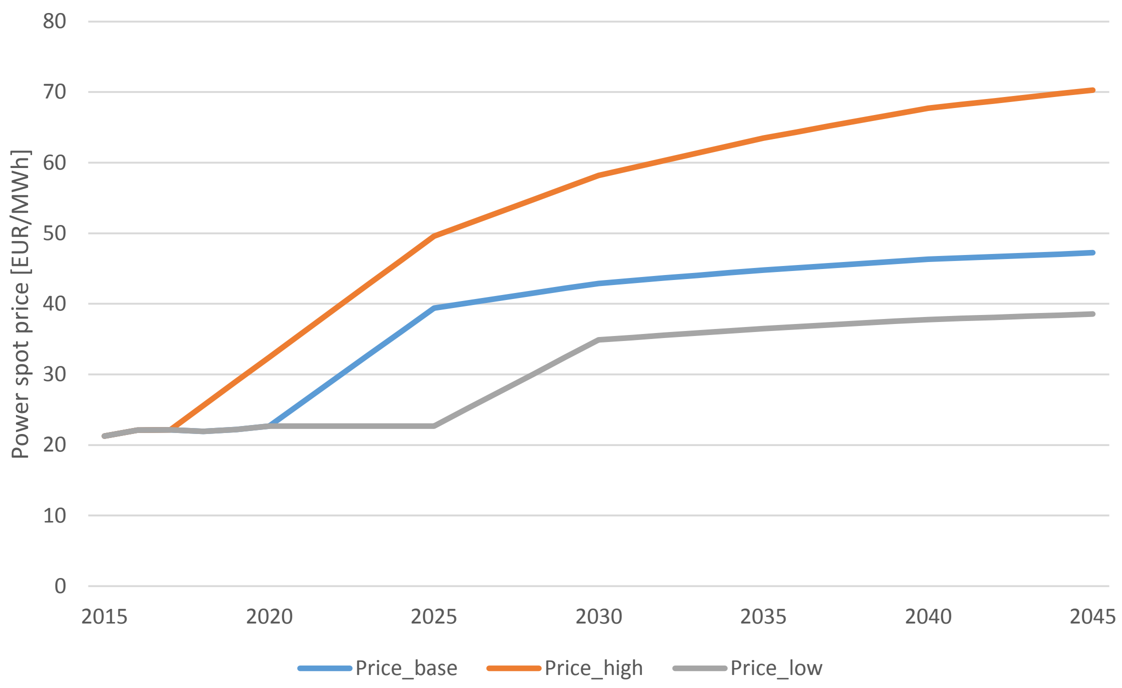
Average yearly price	Price area 1 (North) öre/kWh	Price area 2 öre/kWh	Price area 3 öre/kWh	Price area 4 (South) öre/kWh
2015	19.80	19.81	20.59	21.43
2014	28.60	28.60	28.78	29.04
2013	33.85	33.85	34.08	34.50
2012	27.67	27.72	28.19	29.85

Source: Nord Pool Spot

4.3 Scenarios

There are many potential scenarios on how Sweden's power market and DER can develop. One aspect which influences the electricity market investment decisions to a large extent is the power spot prices. Figure 4-4 shows three different scenarios for future power spot price development in Sweden. The "low case" assumes forward prices (financial current forward prices are available up to 2025) to 2025 and then a relatively low development. The increase in prices is due to increased physical integration with more expensive power markets (such as foe example Germany) and increased prices on emission allowances (since the EU is aiming to increase these after 2020). The Price_base is Sweco's reference scenario, i.e. our "best guess". The high scenario mainly assumes higher fuel prices, which increase spot prices.

Figure 4-4: Potential power spot price development in Sweden, three scenarios

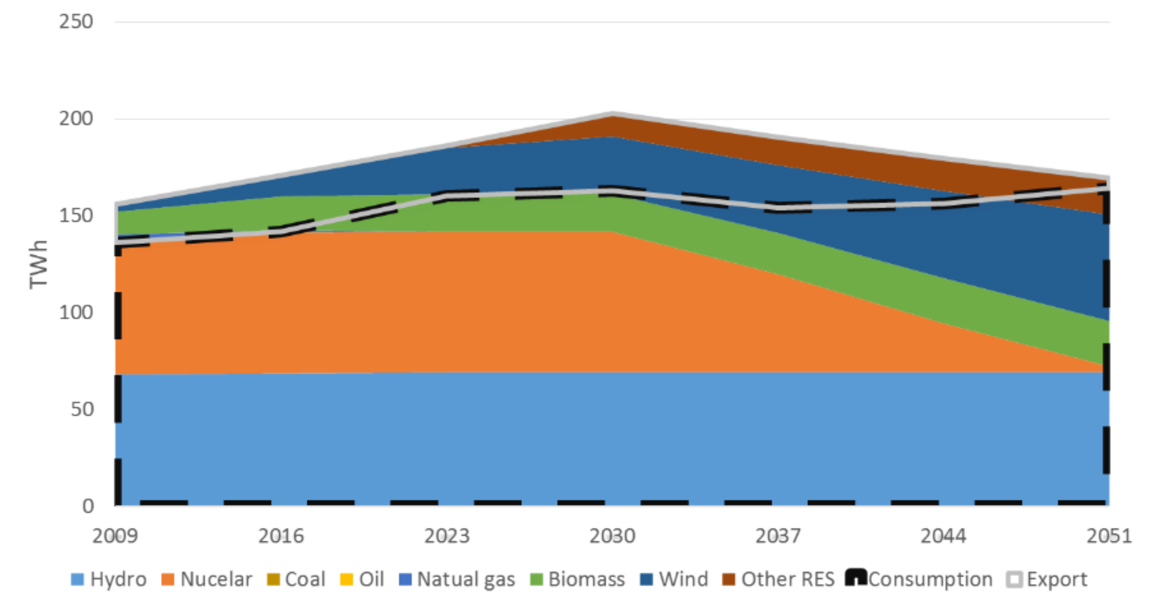


Source: Sweco

A higher spot price will create increased incentives to invest in DER, since the pay-back time will then be lower. However, increased amounts of DER will overall decrease spot prices, especially during hours with a lot of sun. As described in Chapter 5, however, the development of DER is not only dependent upon price signals but also to a large extent social preferences.

A commonly used scenario is the NEPP (North European Power Perspectives) Green Policy (GP). This scenario can be regarded as "extreme" and is used to analyze the consequences of having a future energy system that consists of a very high share of renewables (in terms of, e.g., costs, emissions, handling intermittency, and use of resources). GP includes the Nordic countries, and a major challenge in this scenario is the aggregated effects of wind and solar power (The PV-power is primarily estimated to appear at lower voltage levels). For this scenario it is also estimated that roughly 1 million EVs will be present, amounting to a total of 20 % of the fleet. The energy balance in the GP-scenario can be viewed in the Figure 4-5.

Figure 4-5: The energy balance in GP. Consumption and Export is superimposed on the generation types in the grey and dashed black lines.



Source: Sweco

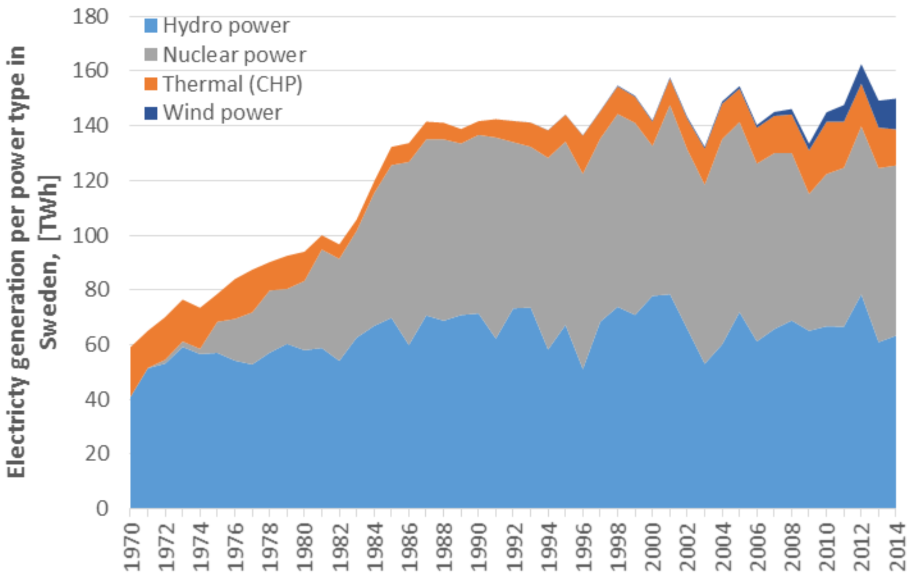
Although price volatility is linked to the transmission capacity in a scenario such as GP, an analysis of the transmission capacity and assuming that no large-scale short-term demand response (flexibility) is developed. As expected the number of hours with bottlenecks and price collapse / price spikes increase, compared with the current situation.

4.4 Development of Electricity production in Sweden

Figure 4-6 overleaf shows development of sources for electricity generation in Sweden in years 1970-2014. It shows that Swedish power sector has experienced growth up to mid-1980s, mainly by enlargement of nuclear generation in 1980s. Since 2010s wind power generation in Sweden increases. Today Sweden is using less energy than its generating and is therefore a net exporter.

It shall be mentioned that the presented CHP based generation in Sweden is preliminarily biomass and waste based. Besides, there are some PV installations in place, however their contributions on large scale remain negligible.

Figure 4-6: Electricity generation per power type in Sweden 1970-2014



Source: Sweco based on data from Swedish Energy Agency

A distinctive feature of the power sector development in Sweden is that for about 30 years annual electricity demand in Sweden remains at the same level of 130-140 TWh since 1980s, while GDP keeps growing - see Figure 4-7 below. Prior to that, the electricity demand increased annually by 4-5%. The processes that together led to the stabilization in demand for 25- 30 years are:

1a) During the 1980s and 1990s, electric heating in buildings (direct-acting electricity and electric boilers) increased significantly, and at a pace exceeding prior years. This pushed the growth of electricity demand upwards.

1b) Since the turn of the century, heat pumps have been installed, at a large scale, for heating purposes in buildings, and this has, in turn, had a declining effect on electricity demand.

2a) During the 1980s, the electricity demand also increased rapidly in the district heating sector; but

2b) in the late 1990s this demand decreased once again.

3a) During the 1980s up to the mid-1990s, the electricity demand in the industry sector increased, both in total number as well as in specific use (electricity per value of output), as a consequence of the significant conversion from oil to electricity.

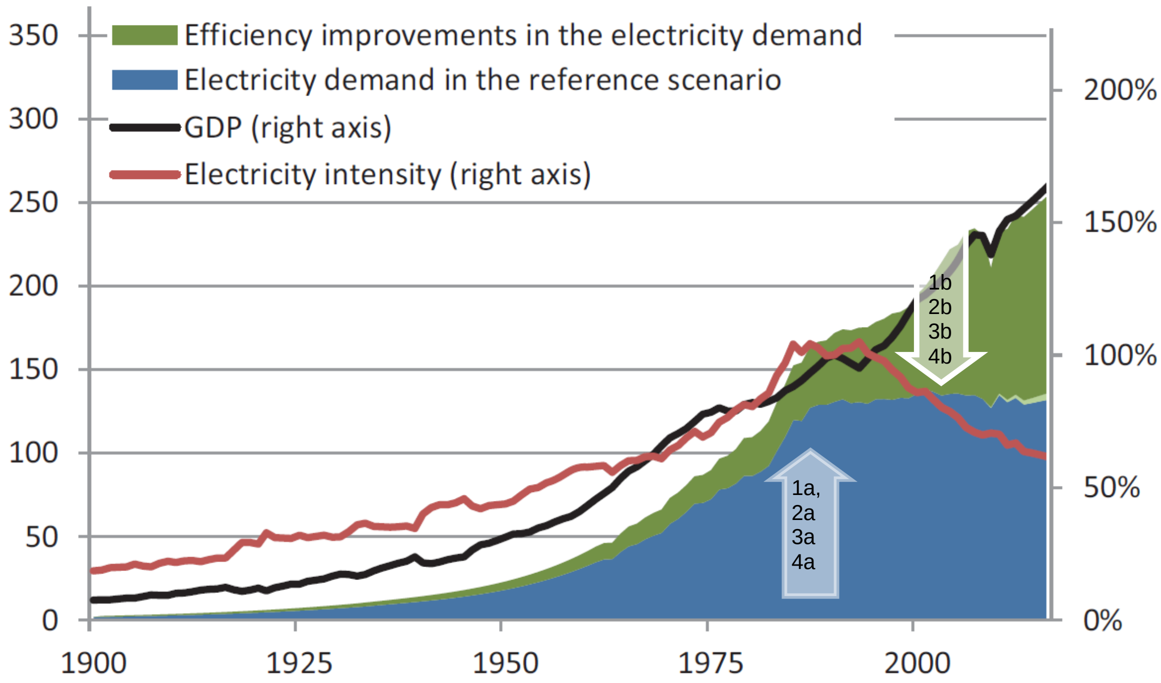
3b) Thereafter, a “decoupling” between electricity demand and production has been established in the industry sector, which has substantially reduced the electricity demand growth.

4a) Within the forest industry sector, the electricity-intensive mechanical pulp production increased rapidly during the 1980s.

4b) This production growth declined during the 1990s, and after the turn of the century, mechanical pulp production has levelled off and during the last years even declined.

Since the financial crisis of 2008, the global economy has slowed down with a significant impact on the demand for electricity. We have seen a declining electricity demand, particularly in the industry sector.

Figure 4-7. Electricity demand and GDP growth in Sweden over years



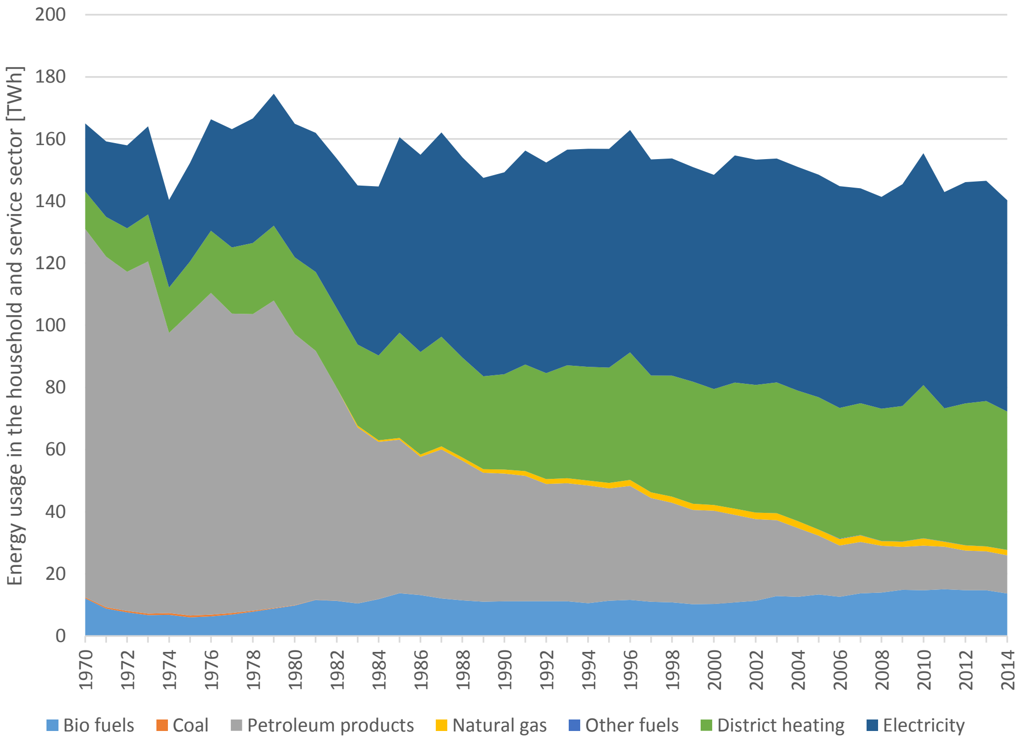
Source: NEPP Electricity Demand in Sweden, 2016

4.5 Development of District Heating in Sweden

Figure 4-9 shows the input energy for Swedish district heating 1970-2014. Before 1980s most of district heat in Sweden has been generated from oil and is an imported resource in Sweden. With oil crisis, a realization of the necessity to substantially change approach to heat generation has arrived to Sweden. The main drivers have been increase of energy security by phasing out of oil from heat generation, and the solution has been found in enhancement of the district heating technology to be able to utilize advantages of the CHP technology and diversify fuels.

By 1990s targeted governmental policies implemented at municipal levels have put coal in advantage for heat generation and substantially reduced presence of petroleum products. Besides, other technologies entered the market such as electric boilers, heat pumps etc. This development is seen in Figure 4-8. This sector includes villas, multiple-family houses as well as offices and stores. A large part of the sector's energy usage is heating (approximately 70 percent).

Figure 4-8: Energy usage in the household and service sector



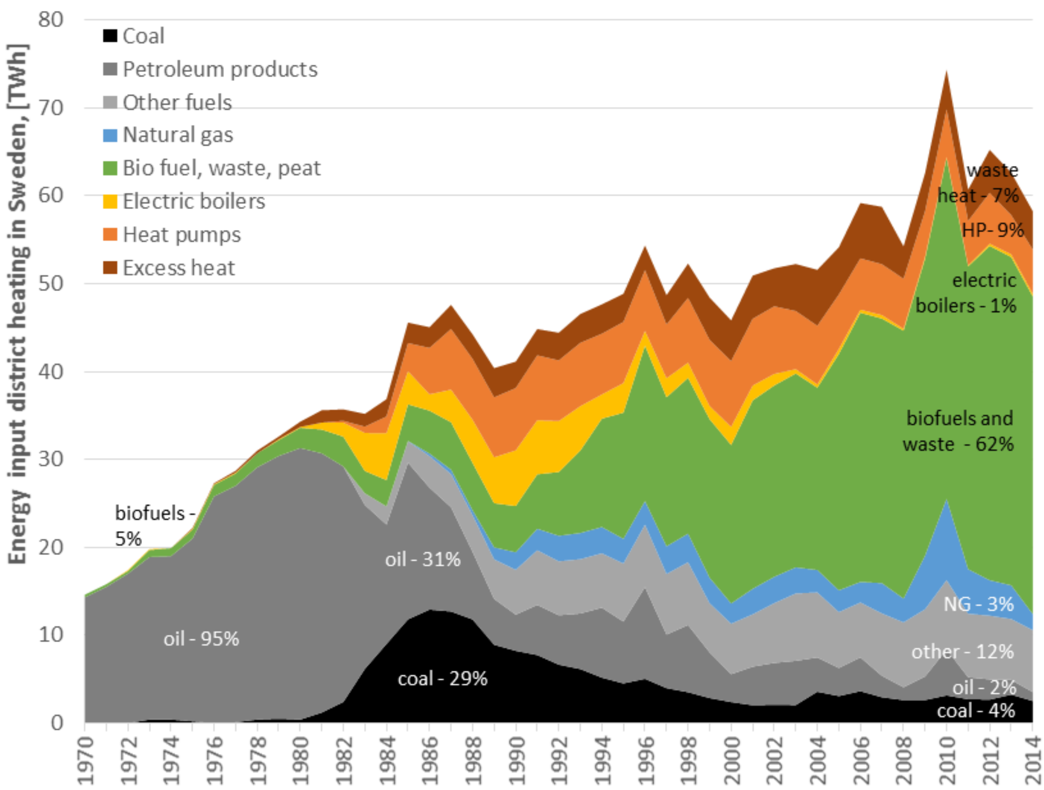
Source: Energy Agency

As can be seen from the figure, electricity and district heating has grown, whilst petroleum products have declined. The expansion of heat pumps during later years is not visible as increased electricity usage in the figure, mainly since heat pumps use electricity more efficient than direct heating. Pure electricity based heat generation is inefficient, and efforts has been made on stimulus towards heat pumps instead of straight electrical water heating.

In the beginning of 1990s sustainability and climate change discussions brought a realization that fossil fuels shall not be preferred. With this, Swedish Government has introduced a CO2 tax that the key policy enhancing further phasing out of oil and recently entered coal. This policy has been complemented with a complexity of other governmental policies and initiatives that together made fossil fuels a non-preferred option for heat generation in Sweden.

By today, Sweden has almost completely de-fossilize its district heating generation – only few per cent of coal, oil and gas are present in the energy mix, while vast majority of district heat coming from sources that are perceived as “waste” in many other countries – biofuels that also include bio-wastes, forest industry wastes and municipal solid waste; as well as waste heat from industrial technologies.

Figure 4-9: Energy input in Sweden's district heating in 1970-2014. The data is not weather-corrected

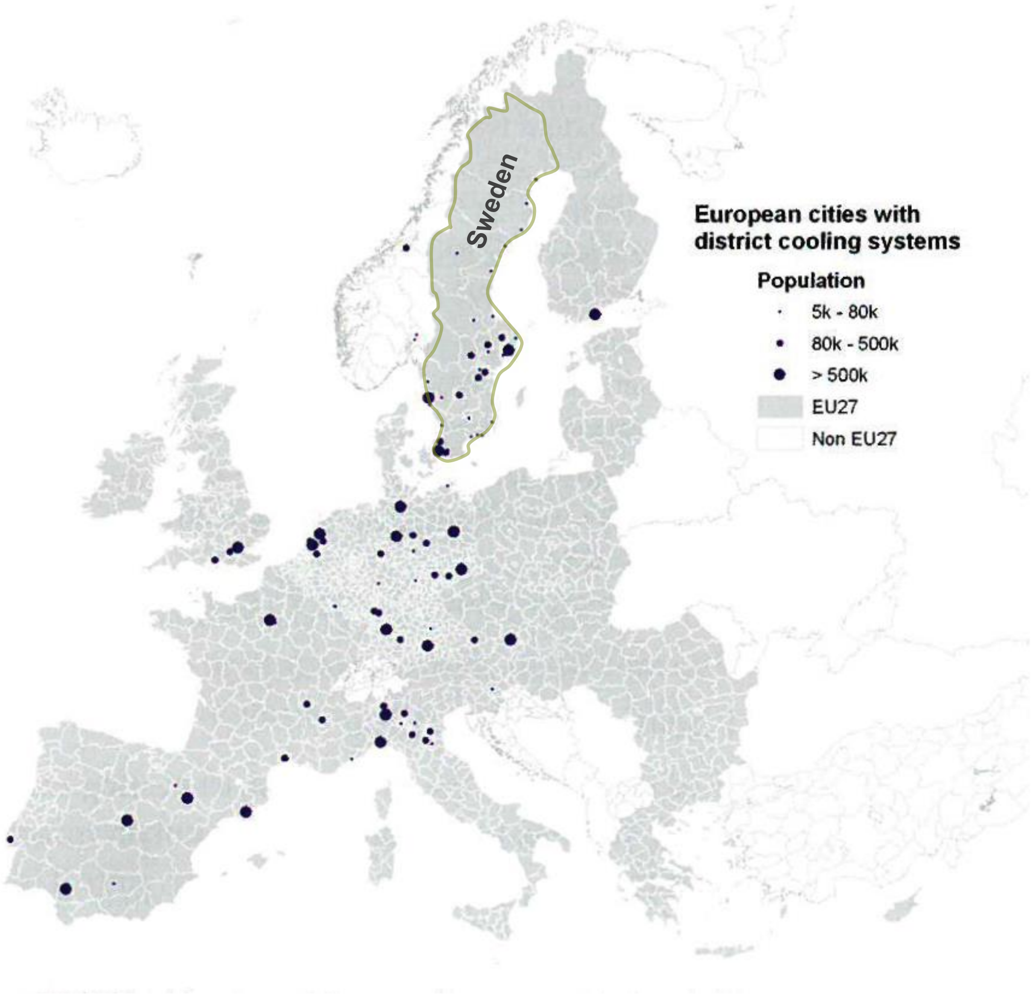


Source: Sweco based on data from Swedish Energy Agency

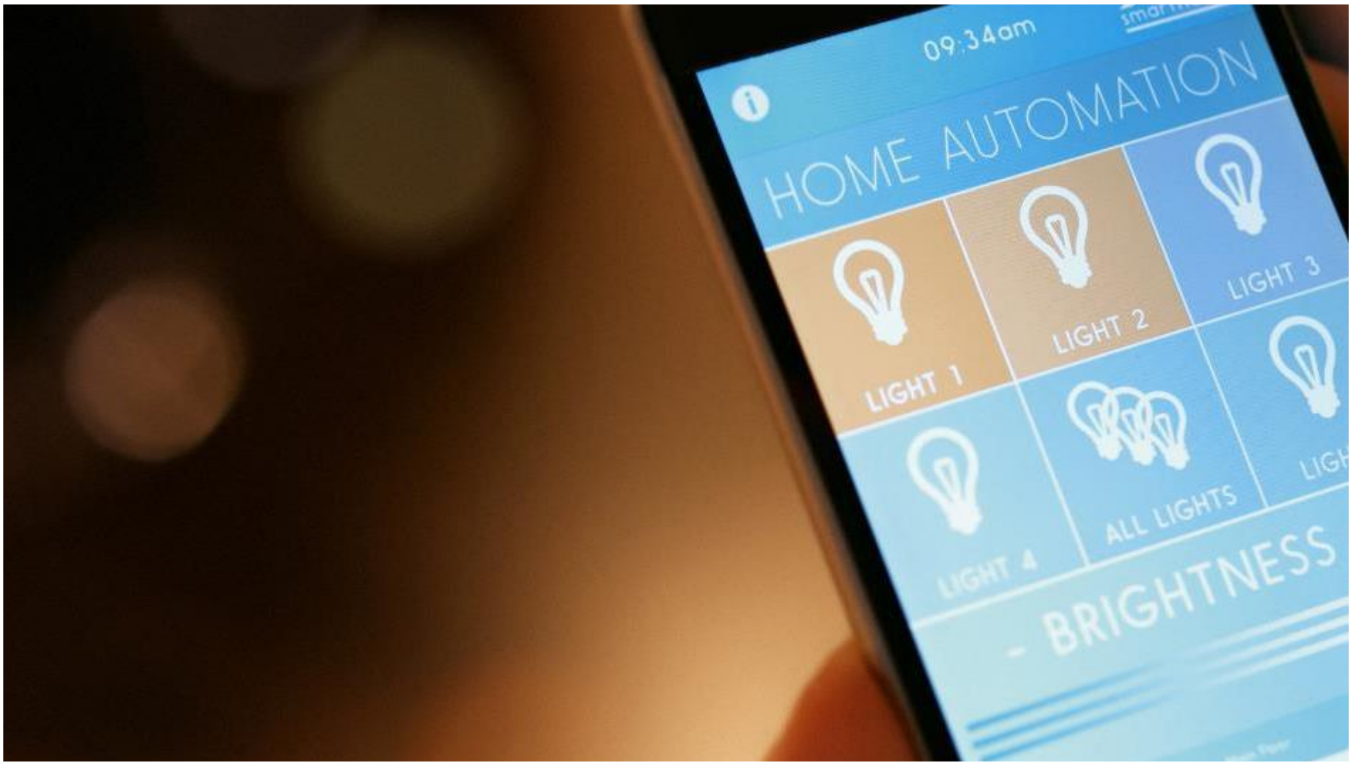
4.6 District Cooling in Sweden

The first district cooling system in Sweden was constructed in Västerås in 1992. Today one of the largest district cooling systems is operated in Stockholm covering about 600 buildings and possessing 200km of pipes. The main drivers behind its development are simpler, safer and cleaner cooling supply comparing to available alternatives (e.g. split units). The cooling has a mix of sources; free sea-water cooling and waste cold from heat pumps provide about 57% of district cooling, and the rest is supplied from HP cooling and a minor share of chillers.

Figure 4-10: District cooling systems in Europe in 2011



Source: District Heating and Cooling, S. Frederiksen and S. Werner, 2014



5 The New Energy Customer

Electricity customers take an increasingly active and important role in the power market. This has already became one of the major discussion topics in the industry, as well as opens up opportunities for new business models to appear.

The behavioral change of power consumers in Sweden has preliminarily non-cost-saving roots: strive for green technologies and environmental awareness are among the most distinctive trends of the Swedish society. This not only affects personal choice of consumers and makes them more responsive towards environmental policies, but also stimulates companies to brand themselves green to be more attractive to consumers, as well as puts additional pressure on policy makers to develop green policies for the further.

A separate trend that is currently gaining momentum is that energy as such becomes cool. This is particularly relevant for owners of stand-alone houses who may consider installations of DER simply because it is a cool thing to do.

Responsiveness and relatively high awareness of the consumers in Sweden is also related to liberalization of the retail power market back to 1990s. This makes consumers more exposed to price volatility and benefit from open competition. Still, far not all consumers are interested in energy questions, there is still a large room for improvement of general consumers' awareness and interest.

At the same time, generally low power prices in Sweden drag back the interest of consumers: the power bills in Sweden are too low to consider demand flexibility. This is true not only for apartment owners whose consumption remains relatively low, but also for industries with significant consumption levels.

5.1 Current Status

5.1.1 Approach towards electricity consumers has changed

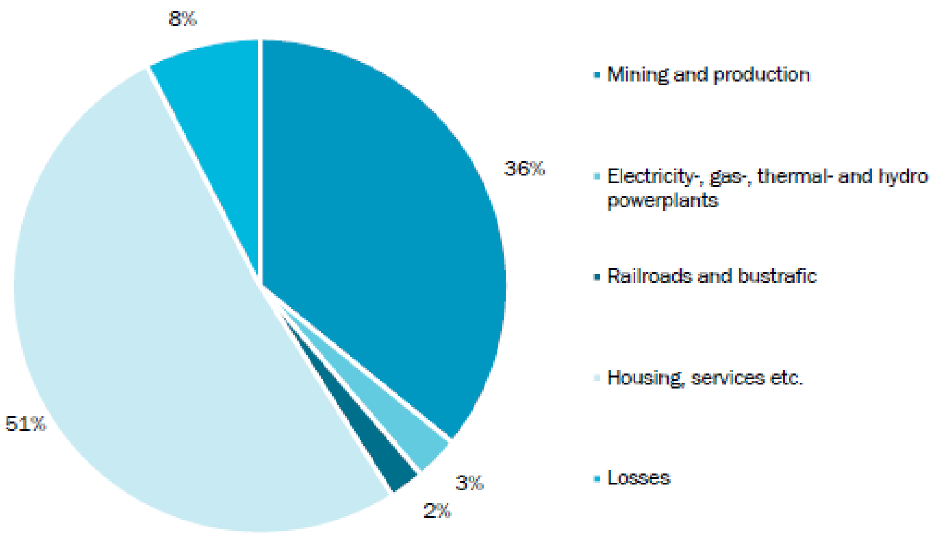
Traditional electrical systems have been based on high reliability in generation and adjustments towards demand profile. The consumption side has been seen as the variable factor, and production has been adjusted to this accordingly. Consumers were treated as bill payers, and their consumption has historically been relatively inelastic to prices.

However, previously regulated end-users with little or no choice today has become customers who can choose when to purchase electricity, how much electricity to purchase and from whom. The approach towards electricity customers is currently changing in order to satisfy these customers with growing conscious consumption and a more active role in the power market.

5.1.2 Customer classes in Sweden

Different customer classes have differing capacities and interest for active participation in the power market. They differentiate in the nature and quality of demand management. The customer classes that could be defined in Sweden are presented below, while their consumption share in seen in Figure 5-1.

Figure 5-1: Electricity consumption by area of use, 2014



Source: Swedish Energy Agency and Statistics of Sweden

Large industrial consumers take a significant share of electricity consumers in Sweden, largely due to the relatively large electro intensive industry in Sweden. A few of these take very an active role at the power market as they can directly put bids at the power marketplace. Consumers of this class usually have technology and skills to actively manage their energy consumption and participate in demand response, even though this is done to a limited extent. This class of customers is usually dynamic to some extent in their demand management, while they have a large potential.

Large and medium commercial consumers do not take direct participation in the power marketplace and receive electricity from a power supplier. They sometimes have power procuring departments and their consumption size it usually significant enough to make it a subject of monitoring and possible optimization. A large share of this class's consumption origins from indoors climate technologies (heating, cooling, ventilation) that have a good flexibility in their demand and thus can create a good demand response potential. Consumers of this kind often possess room available for generation behind the meter. This class of customers have the potential to be dynamic in their demand management, even if they in practice most often are not.

Medium industrial consumers are similar to the commercial consumers, however their industrial technology in use their demands may not always be flexible. Customers are unlikely to choose to curtail their electricity consumption if it is incompatible with efficient management of their industrial processes or threatens contracted deliveries to their primary product markets. This class of customers can be both dynamic and passive in their demand management.

Small scale industrial and commercial consumers usually not have electricity volumes which are significant enough for precise monitoring and optimization. Besides their premises are often areas of larger buildings with integrated engineering systems and limited room for behind-the-meter installations. This class of customers is rather passive in their demand management.

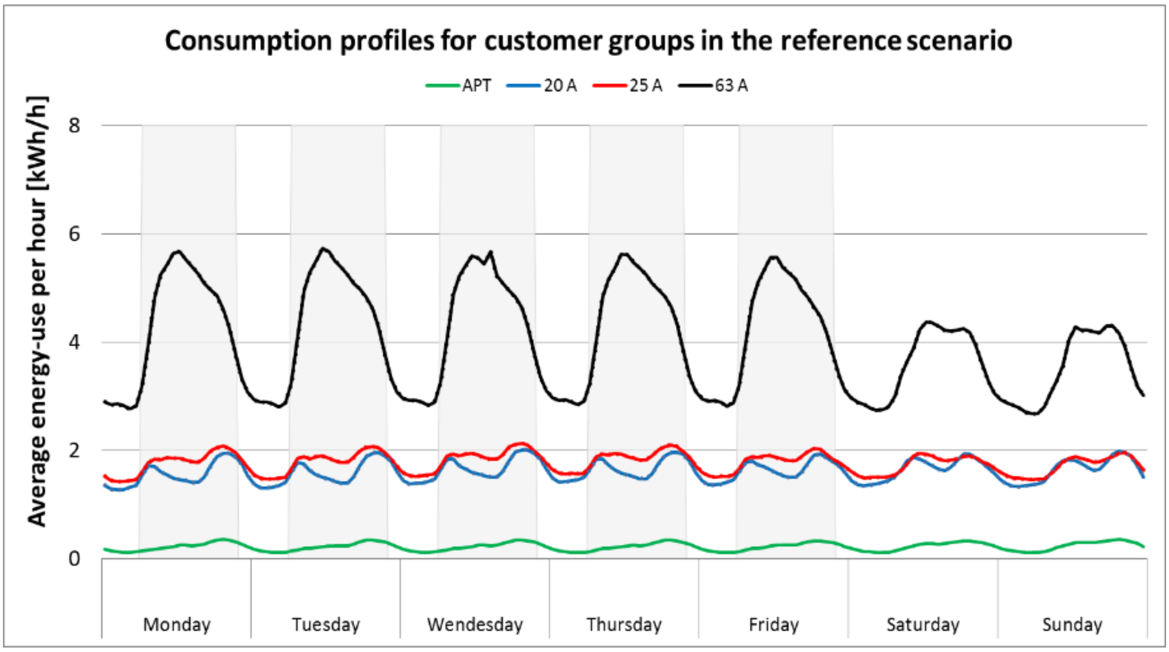
It is rather challenging to determine **residential consumers** into groups based on demographics since customers of the same demographic group can have very different drivers for their consumption patterns (presented in the next chapter). More definitive is to classify residential customers based on types of their housing and hence technologies that they operate and potentially have access to.

Residential consumers – villa owners often have noteworthy energy consumption and origins from indoors climate installations and home appliances. These technologies can be flexible in energy consumption. The most common heating of villas is by heat pumps, although bio fuel (pellets) and district heating (and some others) also occurs. Further, villa owners often have sufficient space for own generation installations. This class of customers can be quite dynamic in their demand management.

Residential consumers – apartment residents in Sweden usually have rather small consumption volumes as they do not control their heating system themselves (this is usually done centrally by the housing society or house owner), and the heating is usually included in rent. Besides, they usually do not have space for behind-the-meter installations. A single consumer of this kind has rather small potential for demand management, but aggregated together it becomes a significant volume. This class of customers is passive in their demand management.

Figure 5-2 shows typical consumption patterns of medium and small power consumers in Sweden. Green line APT – apartments residents; blue line 20A and green line 25A – typical for villa owners with electricity-based heating system; and 63A is a composite of the segments 35A, 50A and 63A and can range for from small/medium industries to commercial buildings.

Figure 5-2: Consumption profiles of customers of small and medium size in Sweden in during an average week.



Source: Sweco

5.1.3 Drivers for behavioral change in Sweden

The drivers described below affect behavior of electricity customers in Sweden. The presented drivers are not the only stimulus of behavioral change among electricity customers in Sweden. Along with them, there is also a complex set of governmental incentives towards DER – they are described in details in section 6.1.4.

- **Societal preference towards green**

Overall societal preference towards green and environmentally friendly technologies is increasing in Sweden. For a few decades is has been one of the main driving forces towards green technologies, energy decarburization and environmentally friendly solutions. This driving force is valid for all consumer classes, thought degree of its effect depends on personal views. Practically this driver can result in such actions such as a customer paying extra for a contract of '100% renewable electricity' (which is common in Sweden), or a residential user deciding to reduce own consumption at peak hours etc.

- **It is Good to be Green**

Societal preference towards green technologies creates stimulus for companies to invest into 'green technology' in order to be able to market themselves 'green' towards their potential clients.

- **Customers' awareness is rising**

Electricity customers become more and more aware of the energy trends, technologies and options for demand management. This trend is enhanced by customers being exposed towards market prices and price volatility.

- **Not all customers are interested in details of their electricity bills**

While some customers experience driver of increased awareness and interest, the other express the opposite pattern of very little interest in details of their electricity bills that are quite complex and advanced in Sweden.

- **Energy becomes cool**

Energy technology moves away from a boring segment, and becomes more and more exciting subject. It is now cool to have a solar PV on top of roof, it is cool to drive electric vehicle etc.

- **Electricity costs**

Sweden experiences low electricity spot prices (about 20 EUR/MWh). The spot price part is usually the only part of the electricity price one can save by DR, i.e. shifting load between different hours. The total price paid by end consumers with tax, VAT and electricity network is however around 150 EUR/MWh. Still, consumers with low demand volumes (small commercial firms, residents of apartments etc.) would not have sufficient price stimulus to change their behavior in order to save a few kWh a month. This driver becomes more relevant for customers with significant demand volumes. The cost of electricity is not the major driver in Sweden today due to low electricity costs.

- **Quality and reliability of services**

Electricity consumers remain expecting high standards of power supply.

- **Keeping old habits**

Residential consumers remain reluctant to change their behavioral patterns in order to manage their power demand. This is particularly true for people who maintain their habits over decades. It is however has been noticed in Sweden that people with well-established habits still can change their behavior as a result of dynamic comparison. By contrast to a static comparison when consumers are compared by volumes of consumption, the dynamic approach implies comparison of change patterns instead.

- **Personal comfort increase**

Advanced indoor climate control and smart home technologies alongside with improved comfort level bring additional possibilities for demand management. These systems, even without smart meters, allow scheduling, controlling and monitoring the consumption of home appliances using a smartphone. Thus strive for improved indoors climate and comfort levels also becomes a driver for enhanced demand management.

- **The consumers of tomorrow are raised with IT**

The consumers of tomorrow are raised with IT, digital media and devices, in a way that is totally different from previous generations, and this might influence what they in the future will expect from, e.g., the electricity companies. The age at which Swedish youth/children are starting to use IT is declining rapidly, and half of the 2 to 3 years olds have come in contact with internet. Which services will this generation expect as adults?

5.1.4 Swedish retail market being exposed to competition

The Swedish retail market for electricity has been exposed to competition since 1996. There is no price regulation.[2] Customers on the Swedish electricity market are free to choose a preferred electricity supplier. This means that companies operate in an open market in competition with other companies and that pricing is discretionary. If the customer does not make an active choice, the relevant network owner is responsible for assigning a default supplier.

Liberalization of the retail market has been done in order to:

- Convey real price signals;
- Enhance efficient and timely investment responses needed to ensure future reliability and affordability as well as minimize overall system costs;
- Enhance effective customer choice and demand management;
- Encourage retail competition;
- Stimulate innovation of market products and technical solutions.

There are a few mechanisms in place that monitor electricity prices and allow Swedish consumers making good choice in selection of their suppliers. For example, electricity supply companies are required to report their offered electricity contracts to the price comparison site Elpriskollen.se. The website is run by the Swedish Energy Inspectorate and allows users to compare prices and offers from different electricity supply companies and by this enhances transparency and fair competition on the market.

Contractual renewal and the threat of switching rather than actual switching becomes a more important driver for innovative product and market development as retail markets mature, especially for larger industrial customers who have considerably more negotiating power than other customers. The Swedish experience of contracts renewal is presented in the chapter 5.1.5 below.

5.1.5 Electricity supply contracts

Figure 5-3 shows the distribution type of customer contracts in Sweden. The most common form of electricity supply contract in Sweden is a variable price contract. Under this contract the customers pays the monthly average spot price plus additional charges. The customer therefore receive a quite efficient price signal, though it is important to recognize that they are also being exposed to a price risk (which in case of Swedish electricity prices is rather limited). It is important that customers are faced with the real average costs of generating and transporting electricity - this will ensure that all market players have the incentive to act in a timely and in an efficient way to minimize overall system costs. There are some contracts with hourly pricing – especially for larger customers. These provides an even better price signal, as they reflect the value of electricity during different hours and creates incentives for DR.

There are about 15% of customers who follow default contracts. These customers have paid about 20-30% more comparing to customers who made an active choice in selecting electricity supply contract. Share of default contracts in Sweden in reducing.

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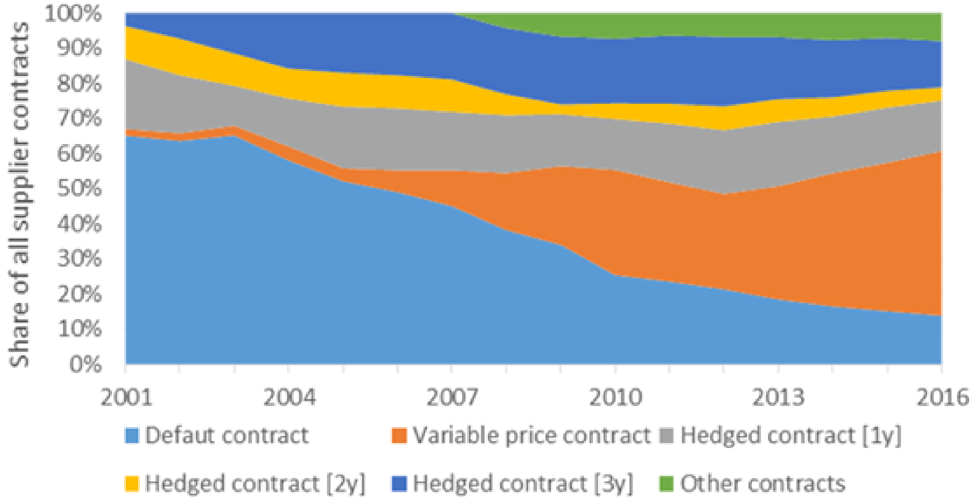
[2] However the networks are regulated monopolies and their revenue cap is regulated (even if the tariffs are not)

Figure 5-3: Distribution of types of supplier contracts in Sweden 2001-2016



Source: Sweco

5.1.6 Rate of customer contracts renewals

A good indication of customers' dynamics and active choice is renewal of their supply contracts. Sweden has one of the highest switching rates in Europe.

With introduction of competitive retail market, the rate of residential customer switching has increased steadily over the years rising from 10% of residential customers in 2000 to 18% in 2002, and to above 30% in 2005. In addition, it is estimated that a further 25% of residential customers have renegotiated or switched away from standard contracts offered by their existing suppliers.

In practice, customer switching tends to be higher for an initial period following market opening, and then stabilize over time. In case of Sweden, the rate of contract renewal became about 6% in 2007.

In the recent few years rate of contracts renewals has been rather stable. In 2014, a total of 552 000 switches of electricity supplier were made, 73 000 of them by corporate customers. In total, about 10% of customers switched their electricity suppliers in 2014 in Sweden.

5.1.7 Prosumers

This is growing in Sweden today, however at a very low level. Prosumers are then described in section 5.3.2 below with a more forward-looking perspective.

5.1.8 Why Demand Response?

Demand response increases electricity system flexibility, with the potential to substantially improve market efficiency, end-use efficiency and electricity security. Greater flexibility from demand response can also help to facilitate the timely and secure large-scale deployment of variable renewable generation.

From an electricity security perspective, demand-side participation has the potential to support a more flexible, innovative and efficient delivery of power system security at lower cost.

From a sustainability perspective, demand response has the potential to greatly increase the volume of real-time flexible resources available to support large-scale integration of variable renewable generation. It also offers the potential to smooth volatility in electricity demand, which may reduce overall carbon emissions by replacing carbon-intense forms of peak generation with lower-emitting generation options at off-peak hours.

Over time, improvements in end-use energy efficiency could result in a permanent reduction in demand compared to previous levels in the absence of demand-side flexibility. This may result in a permanent reduction in carbon emissions where the power saved would have been produced by fossil fuel generation.

5.1.9 Possibility for demand flexibility among industries and service sector

In December 2015-February 2016 a questionnaire and interview study has been performed by Sweco to analyze demand flexibility in Sweden. Respondents belonged to four segments:

1. Electricity intensive industries;
2. Other industries;
3. Real estate[3], and
4. Services[4].

The questions asked aimed at identifying the extent to which the concept of demand flexibility is known among consumers, the opportunities for demand flexibility that are in place now, the extent to which demand flexibility is offered today, as well as the barriers to higher demand flexibility in the future.

The conclusions that can be drawn from the survey is that demand flexibility currently offered primarily by companies in the segment of electricity-intensive industries. These are the largest companies in this segment that is most flexible - most energy-intensive businesses is in the current situation are not flexible to any great extent. Businesses and organizations in the other segments are mostly not particularly flexible today.

The concept of demand flexibility is a relatively unknown concept in all four segments. Increased knowledge sharing on demand flexibility is a necessary but not sufficient measure for greater flexibility in the future. Most respondents indicated that they are unlikely to have any potential for flexible electricity consumption. The most common objection to demand flexibility was that it interfered with business processes. Companies and organizations in the segments of real estate and service pointed out that their activities were very customer oriented and that therefore there is a little opportunity to change consumption based on rapid progress in the electricity market. Industrial enterprises often have production processes that are very sensitive to disturbances, and demand flexibility was considered to hamper firms' ability to deliver on time to their customers.

Other respondents felt that the current low electricity prices lead to low reimbursement rates for demand flexibility, making it unprofitable to adjust electricity consumption - the adjustment affects the business and the costs that this entails exceeds the compensation one can get today for its flexibility.

Many respondents indicated that they would be more flexible in the future, provided that they invest in new equipment and various automated support systems to provide production managers the tools necessary to make decisions about adjustments to electricity. The vast majority of respondents indicated that it was difficult to obtain a basis for decisions about these investments. First, it is difficult for companies to estimate the costs associated with demand flexibility. Moreover, it is difficult for companies to form an opinion about the levels of compensation they can expect in the future.

Demand Flexibility is perceived by many respondents as a complex process. Above all, smaller power consumers are often interested in energy efficiency as a way to protect themselves against higher and more volatile electricity prices in the future. The larger electricity consumers often find it easier to be flexible, but even these companies feel that it is difficult for companies from the point of consumption to offer flexibility in the various markets available for this. The solution to these problems is likely to be aggregators for the smaller electricity consumers and regulatory developments in the markets for large consumers.

Finally, a number of respondents pointed out that the tariffs were sometimes designed in a way that does not encourage a flexible electricity consumption. The solution here is incentive for network operators to offer network contract that is not difficult for electricity consumers who want to be flexible.

The charts presented below illustrate most indicative survey results of the study.

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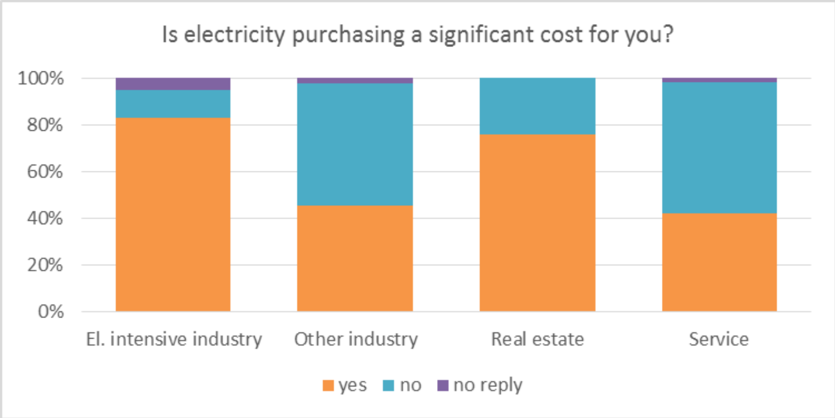
[3] This category is pre-defined by the Swedish statistics, and mainly refers to apartment houses. Private one-family houses are not included in this category and were not included in this interview.

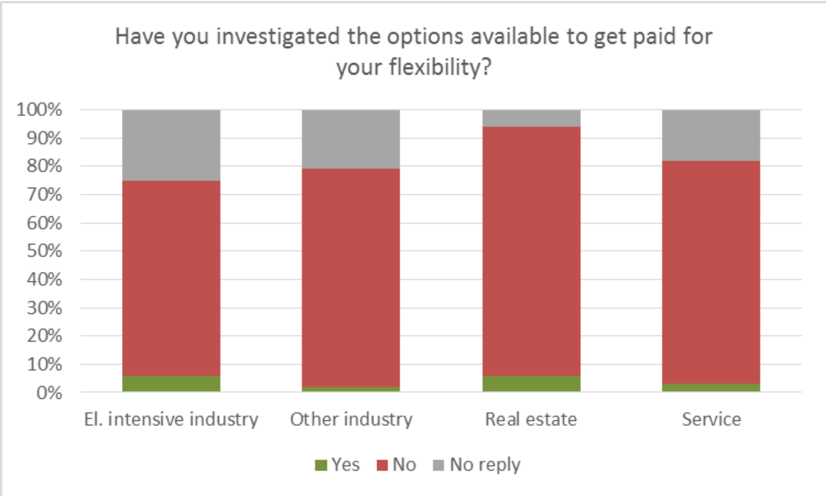
[4] This category is pre-defined by the Swedish statistics, and refers to stand-alone buildings entirely used for services (hotels, shopping centers etc.).

Figure 5-4: Survey responses: Is electricity purchasing a significant cost for you?



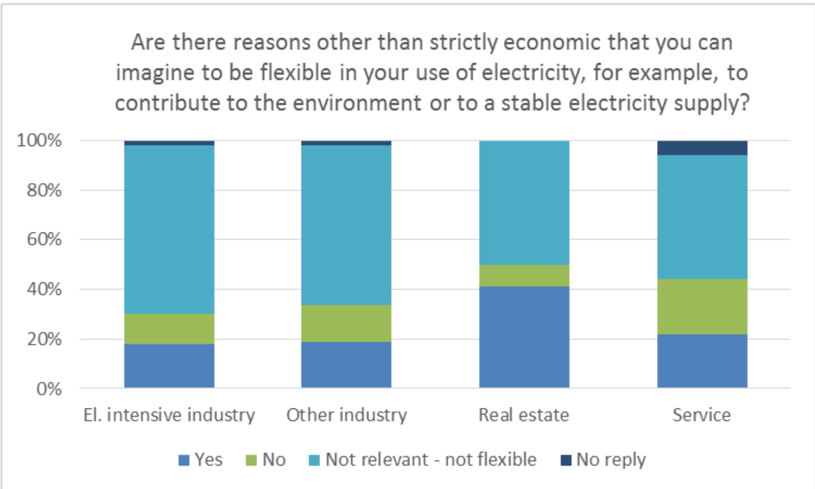
Source: Survey performed by Sweco, 2016

Figure 5-5: Survey responses: Have you investigated the options available to get paid for your flexibility?



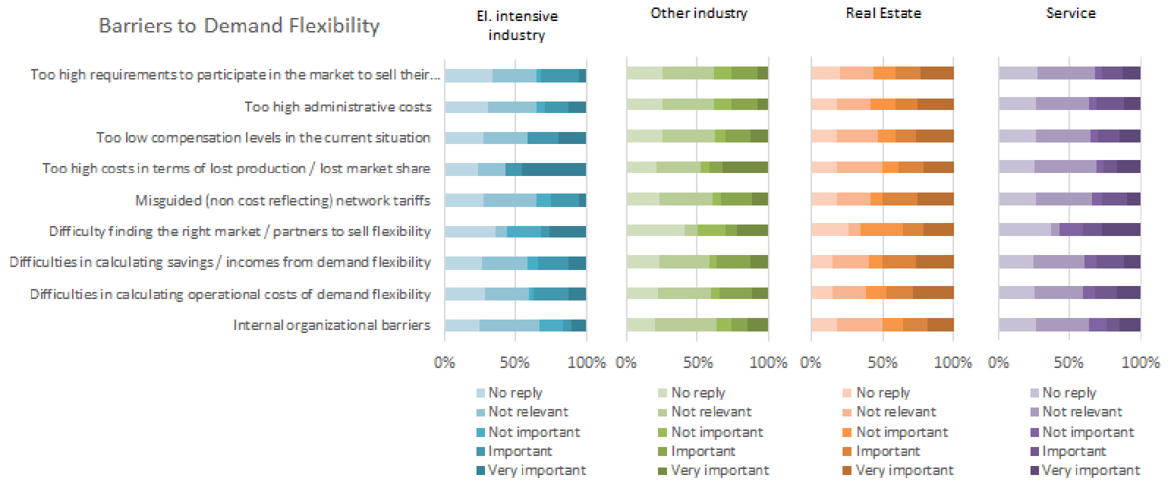
Source: Survey performed by Sweco, 2016

Figure 5-6: Survey responses about reasons other than economic reasons for demand flexibility



Source: Survey performed by Sweco, 2016

Figure 5-7: Survey responses on barriers towards demand flexibility



Source: Survey performed by Sweco, 2016

5.1.10 Vulnerable customers

Sweden does not have mechanisms supporting vulnerable electricity customers. This is because such mechanisms would imply intervention into market price setting. This would weaken price signals for more efficient end use, inhibit development of dynamic and innovative retail competition, as well as distort investment and consumption decisions by firms and households. Instead, Sweden possesses a system of social support to such groups of population. This system do not interfere with electricity market and thus do not distort its price signals. The support is provided in a manner of targeted transfers, and the people who receive it remain free to act at the electricity market following general rules and original price signals.

Besides, there are a number of authorities in Sweden that monitor and enhance transparency at the Swedish power market in order to ensure its equality and fairness. These authorities have been briefly mentioned in Chapter 4.1.

5.2 Lessons Learned

5.2.1 Implications of retail market liberalization

In the early years after retail market liberalization in Sweden in 1996 the electricity prices were very low due to i) excess capacity, and ii) a row of wet years leading to large hydro production. In that period the suppliers were quite active in trying to bundle services and had a strong focus on the retail segment (since they did not earn much money on generation). They were not very successful in doing the bundling. When wholesale prices increased the retail segment got less attention.

Customer resistance was rather limited. Complaints occurred at times of higher prices, though this has not been significant. At the same time, some complaints occurred on the regulated part (networks) saying that the regulation is not effective enough in keeping tariffs down.

Competition has generally worked well in order to limit margins in the retail market. But, there were customers that were inactive and that have not benefitted from the competition. The default supplier option is generally not very attractive; this option can be changed either by changing the supplier, or by signing another contract with existing supplier. Switching has not been very high, but in relation to many other subscription services (e.g. banking, insurance) it is not low either. Most of the customers that have been inactive did however have very low consumption (e.g. apartments), but there were customers with larger consumption that were also inactive.

On the retail side a lot of the benefits from increased competition were hidden from the customers since the politicians took the advantage to increase taxes.

5.2.2 Low interest from customers in hourly metering

On the 1st of October 2012 the possibility for electricity customers, with a fuse of maximum 63 ampere, to have hourly metering of electricity usage without paying any specific additional cost for this, was introduced. An analysis report from 2013 however showed that the customer's interest remained low. A report from 2014 concluded, among other, that the reform continued to have a low impact on the Swedish electricity market. It also showed that still only a few customers (about 8600 customers) decided to sign hourly agreements with their suppliers.

A study carried out in 2014 at the Swedish Umeå University, on customers' consumption flexibility and incentives available to change prevailing consumption patterns, showed that current economic incentives for individual households to switch their electricity consumption during the day are extremely small. The compensation that an average household would need to systematically control their electricity consumption is significantly higher than the current incentives. Thirdly, the price for the consumer to change their behavior depends on when, how and which household it concerns.

5.2.3 Key preconditions for accelerating demand response

The key preconditions for accelerating demand response include:

- Increasing exposure to real-time pricing, with protection of vulnerable consumers addressed through targeted transfers that do not unduly distort efficient price formation;
- A competitive, dynamic retail market to encourage the development of innovative products and services that can harness demand response effectively and at least cost;
- Ready access to detailed, real-time customer information, to help stimulate competition, facilitate competitive entry, support the emergence of innovative business responses, and improve the quality of customer choice;
- A knowledgeable and well-informed customer base that has the capability and opportunity to take full advantage of customer choice;
- Market processes for contracting, switching and billing that are as simple and seamless as possible to keep transaction costs to a minimum;
- Legal and regulatory governance frameworks that reduce uncertainty, establish clearly specified rights, responsibilities and obligations on contracting parties, promote greater harmonization of standards and functionality specifications, and maximize scope for participation among potential service providers and customers;
- Enabling technologies that provide cost-effective, real-time metering information, verification and control capability to support the introduction of real-time pricing, the development of a wide range of innovative demand-response products, and greater customer participation.

5.3 Going Forward

5.3.1 The future is consumer oriented

Traditional power markets are expected to be transformed into more consumer focused markets. Consumers of the future are expected to play an active role on the power market with providing for example electricity production, flexibility to the system and ancillary services. The central suppliers of electricity will need to adapt to the needs and terms of the consumers.

A customer focused approach does not mean that we expect that all customers will be active in supplying flexibility or participating in the different markets. First of all, we expect that most customers are not particularly interested in spending a significant amount of time or resources on this, i.e. very few customers will be active themselves on a day-to-day basis. Rather there will be solution providers of different kinds that will support the customers and enable their market participation. We expect that so called aggregators are likely to play a key role not only for demand side participation but also for other DERs (e.g. small scale generators).

Secondly, the possibilities for customers to actually supply flexibility will differ. Some customers will have a significant amount of flexible load, at least at some points in time. Looking at the household sector it ranges from large houses with electric heating or significant cooling demand, to small apartments with limited electricity consumption. Such differences also exist in other sectors. The key will be to enable participation of the customers that have the underlying potential for flexibility. If this is successful it will also benefit non-active customers since it reduces the overall cost of the system.

Today, customer focus becomes one of the main topics to discuss at the Annual General Meeting of branch organization connecting Swedish energy companies. It has been admitted that sustainability and customer focus (satisfaction, involvement of consumers) dominated discussions of Swedish energy companies (producers, distributers, traders of electricity, heating and cooling) while developing common vision 2050. The goal is to release the Vision in June 2016.

5.3.2 Prosumers

Consumers that possess generation capacity (on their own premises) are summarized as “prosumers”. In the residential sector this can be households that acquired roof top PV panels with integrated battery storage. The commercial sector also (such as shopping malls) also have PVs. Hospitals, data centers, banks and some large industries have DER back-up power.

In a system with significant contribution from distributed small-scale generation a substantial share of the capacities, thus generation, will be installed at end-user premises. Hence, the amount of prosumers, e.g. consumers that produce, are expected to grow. The share of annual production and consumption will vary between different actors, however during certain hours these prosumers will exceed their local consumption with their local generation, and start to feed on to the distribution grid.

One aspect of the situations when the prosumers are feeding into the grid is the forecasting of generation and related balancing responsibility in the system. In the case when there is a significant in-feed from the prosumers in the region the grid might become congested, and generation from one or several of these prosumers will be adjusted or even curtailed. This indicates the need for coordination between the DSO and the balance responsible party, and a way how prosumer can be integrated into the system balancing process. Thus, the prosumer is anticipated to have a stronger relation with one or several of suppliers, balance responsible parties, the DSO/TSO.

The prosumers both generate and consume electricity and with a more volatile price pattern, business opportunities will arise where then prosumers take a natural part in the value chain. Furthermore, the prosumers might become complex actors as they will procure additional flexibility in terms of energy storage schemes.

The system effect from increased prosumers are described the further in chapters.

5.3.3 Nordic harmonized retail market

The Nordic Energy Regulators (NordREG) has worked towards a harmonized retail market since August 2005. The Nordic tradition focuses on creating a customer friendly market in which obstacles for establishing operations in the competitive market should be low. The identified areas for the Nordic harmonized retail market include:

- Combined billing,
- Supplier switch and customer moving,
- Information exchange, and
- Customer interface.

A harmonized Nordic retail market has several benefits:

- Customers have a greater choice of supplier and better opportunities to change to a new supplier and/or new product;
- New suppliers will have more incentive to establish themselves on a larger market due to economics of scale;
- Suppliers will have more incentive to develop products and new types of contract as well as specialist products;

- Automated and simple procedures for customers changing supplier will enable greater efficiency and reductions in suppliers' costs;
- Greater coherency between pricing on the wholesale and retail markets and thus possibilities for better usages of energy.

The result of the process will be a supplier centric model that is the most customer friendly market model. From the Swedish side the process is driven by the Swedish Energy Inspectorate, and the key processes are presented below.

With regards to the information exchange, there should be a centralized information exchange model which would cover the key processes in the electricity market. Processes such as switching and moving should be carried out in the hub. The hub should also be an access point for the competitive stakeholders to the electricity market. The Energy Inspectorates believes that it would be easier to establish business in the Swedish electricity market if you only have to be in contact with one point rather than different DSOs, depending on in which area the customer lives.

The Energy Inspectorate suggests a regulatory framework for a supplier centric billing regime were the supplier is responsible for billing, both for supply and distribution. In the proposals the supplier bills on behalf of the DSO but is always responsible for paying the DSO even though the customer does not pay the supplier.

Model for efficient customers moving is of the key aspects of the process. The customer should only be in contact with the existing or new supplier in order to make a move in or out. This would also mean that fewer customers will have a default contract which has a positive implication by itself as the default contract owners pay about 30% more comparing to other types of contracts. The issue arises since about 80% of the customers get a default contract when moving. The Swedish Energy Inspectorate proposed that the supplier should take care of the move out and move in process.

With regards to the switching, Sweden already has a supplier centric switching process so there was no need to make any changes in that process.

The processes of establishing Nordic supplier centric model are ongoing.

5.3.4 Large amount of demand flexibility is estimated at consumer end

The future-oriented studies estimate that demand flexibility offers a technical potential for a capacity reduction of at least 4000 MW in Sweden. This is a significant potential and is equal to almost 15 % of the maximum national capacity peak.

The potential for demand flexibility in industry is tightly coupled to price elasticity, i.e. the relation between demand and price of electricity. The potential for load reduction in Sweden is estimated to be approximately 2000 MW when the electricity price passes 200 EUR/MWh. The potential for demand flexibility among households with electric heating is estimated to be a little bit more 2000 MW, equaling 2 kW in app. 1 000 000 single-family houses. The potential is this large in this customer segment because of the possibility to use these houses' heat inertia to move the load a few hours without impacting the comfort. If a lower comfort can be accepted, the potential is even larger.

Table 5-1: The potentials for various types of demand flexibility in Sweden

Sector	Total potential (MW)
Industry	1900-2300 MW
Single-family houses with electric heating	2000-2400 MW
Shopping centers	40-50 MW
Offices	140 MW
Schools	10-20 MW
Total potential	**4000-4500 MW**

Source: NEPP 88 pearls of wisdom, 2016

In a longer perspective also other kinds of demand flexibility might come into play, e.g. moving load through adjusting the timing for electric vehicle charging, or adapting the use of household appliances based on differences in price between different points in time.

An important basis for the implementation of demand flexibility is that the measures should be market-conforming and thereby profitable for the participating parties. To make the price of electricity useful as a control signal for adjusting the demand, price volatility is necessary, which makes it cost-effective to move load from high-load periods to low-load periods.

Demand flexibility is expected to be driven by high prices (which are rather low currently in Sweden). At the same time, demand flexibility will lead to a levelling out of the electricity price by cutting the peaks, but also by raising the price during low-load periods. An increased demand flexibility will thereby reduce the price volatility. In this way, promoting demand flexibility will - paradoxically enough – also counteract the incentives for a further increase of demand flexibility. Thus, there might be a balance that limits how much demand flexibility that is really lucrative.

The current prices of electricity do not vary enough to give sufficient incentives for demand flexibility for an electrically heated single-family house. But time-differentiated network tariffs can be an effective control signal for demand flexibility in households.

An increased demand flexibility will also lead to an improved energy efficiency. The field studies that have been made show energy savings of around 10 - 15 %, when customers become aware of their consumption and optimize their heat supply. The reduced demand might be the prime incentive for investing in demand flexibility.

5.3.5 The energy customer of the future

With the described ongoing drivers and existing outlines on the futures of the Swedish power market, the energy customer of the future is seen to possess the following features:

- It is generally aware of energy trends and is interested in energy processes;
- It is exposed to the market volatile prices and knows how to navigate there;
- It does energy improvements because they are cool and good for environment;
- It is an active participant o of the energy system:
  - Produces energy;
  - Stores energy;
  - Participates in the power market;
  - Provides flexibility to the system
  - Yet does not jeopardize its own comfort levels and requirements towards system reliability and stability.

The new energy consumer also implies related adjustment of roles of other electricity market actors.

6 Meeting Energy Demand Behind the Meter

Because of the market design, there is very little regional planning of power generation in Sweden. There is no limit to how much DER can be introduced in a geographical area, the network company is obligated to connect all power generation and the view is that the market should create the right incentives to locate power generation were its most appropriate.

In Sweden DER is currently in operation only to a limited extent. The fastest growing DER is micro solar production and electric vehicles. Additionally, some industries in Sweden produce their own electric power behind the meter – this is usually a requirement for process steam and to some extent due to a surplus of suitable waste fuels (mainly pulp and paper industry).

DER is politically encouraged in Sweden and there are multiple support systems and tax exemptions in place to create incentives for DER (mostly for distributed generation). In practice this has mainly led to the installation of small-scale solar production units. Governmental supports systems and tax exceptions for small-scale generation include:

- **Investment support for solar production**
- **Tax deduction for households for instalment of DER (lower labor cost). Cannot be received if investment support is received**
- **Exceptions from electricity tax (when using own-produced electricity), additional tax deductions (when feed-in)**

- **Reduced network cost for small scale producers (not only renewables)**
- **Electricity certificates (for all renewable production, also large-scale)**

Net metering for micro producers of small-scale renewables is used in other countries and have also been discussed/tested by some grid companies in Sweden. A governmental investigation drew the conclusions that net metering is against the EU's VAT directive. Net metering has been criticized in Sweden since electricity which is fed into the grid during one hour can have another market value than the electricity it is offset during another hour. It has therefore been argued in Sweden that net metering removes the price signals and the incentives for demand response. On the other side, some have argued that net metering is simpler for all stakeholders involved.

From a tax perspective small-scale production has stronger incentives than large scale renewables in Sweden today. From a socio-economic perspective it is quite unclear why the small scale production should be favored over large-scale production.

Even if small-scale renewable production in Sweden has a lot of financial incentives, many stakeholders argue that there are too many different support schemes and exemptions, that it is too complex to be considered as a genuine supporting mechanisms by potential micro producers, especially taking into account the extensive application processes. They also argue that the current system does not send the right signals by for example paying back the tax savings only once a year, rather than continuously.

The fastest growing DER is micro solar production and electric vehicles. The use of batteries and energy storage is today very low but this is expected to grow, especially in the form of batteries in electric vehicles.

Sweco has identified three types of benefits with increased DER:

- **Production closer to load, which reduced grid losses**
- **The possibility to include more renewables**
- **The possibility for DER to help balancing the system, especially DR**

The main identified challenges with increased DER are:

- **Distribution grids having to handle reversed flow (at times with large distributed production)**
- **Feed-in of distributed renewables sometimes dimensioning for the local grid (rather than the maximum load)**
- **Increased intermittent electricity production**
- **Decreased usage of grid infrastructure and large scaled generation (resulting in stranded assets)**

6.1 Current status

The following sections presents the current status of DER in Sweden as well as relevant development incentives.

6.1.1 DER today

Distributed energy resources (DER) consist of small- to medium- scale resources that are connected mainly to lower voltage levels (distribution grids) of the system or near the end users. Key categories are:

- Distributed generation (DG): power generating technologies in distribution grids. The category comprises dispatchable resources like cogeneration units or biogas plants and variable renewable energy sources (VRES) which depend on fluctuating conditions such as wind and solar irradiation.
- Energy storage: batteries, flywheels and other technologies that store electric power to be supplied at a later point in time
- Demand response (DR): Changes of electric usage by end-users from their normal consumption patterns in response to market signals such as time-variable prices or incentive payments

In Sweden DER is currently in operation only to a limited extent. The fastest growing DER is micro solar production and electric vehicles. It is not common with other kinds of electricity production behind the meter than solar production, but some wind power is fed into the local grid level. The use of batteries and energy storage is very low but this is expected to grow, especially in the form of batteries in electric vehicles.

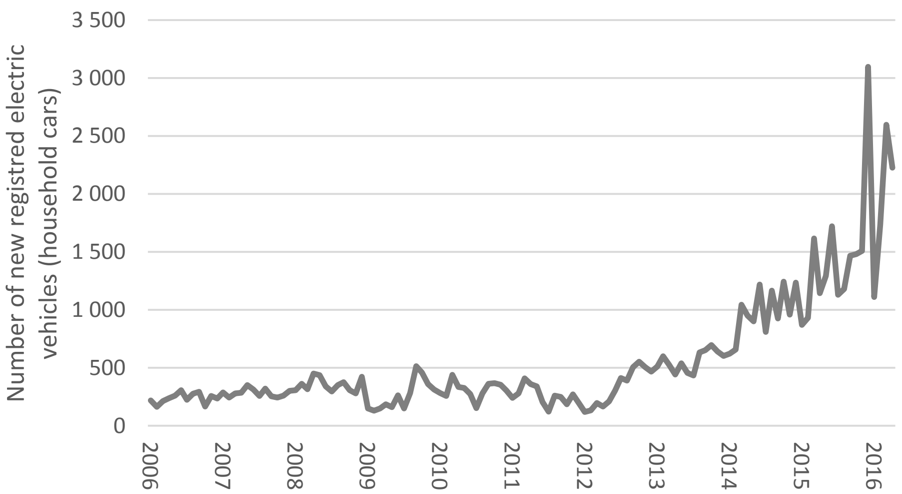
There is an ongoing discussion about demand response and the role it could play in Sweden. However, at the household/commercial level, there has not yet been any significant development with the exception of demo units. There are some large industrial players using demand response and taking part in the balancing market. The concept of “Smart homes” is also being discussed. It should however be mentioned that "Smart homes” generally only require limited energy volumes and are perhaps not suitable from a DR perspective. Automatic control of heat pumps is however relatively well developed in Sweden and these, combined with buildings’ thermal mass, are expected to grow in regard to demand response.

6.1.2 Households and commercial DER

The main DERs for commercial and household customers in Sweden today is solar panels and electric vehicles. In both cases, owners of private households are the main group operating these DERs. Solar panels on commercial buildings such as offices, shopping malls etc. are growing. Also, a relatively large part of the taxis are electric vehicles.

In Sweden there are currently 19 323 electrical cars (electricity and electricity hybrids). The total number of cars (in use) in Sweden is 4 773 850, meaning that electric vehicles accounts for approximately 0.4 percent of the total fleet. However, the sales of electric vehicles are increasing, see Figure 6-1. Many people in Sweden expect the sales of electric vehicles to boom sometime during the close future. This is driven both by the political incentives (see Chapter 6.1.4) and the technical development of EVs making there driving range increase and the investment cost decrease. As mentioned above, a relatively large part of the taxis are also electric vehicles. The taxi companies wants to have a green profile, and there are also some benefits associated with it (for example shorter queue to customers at airport).

Figure 6-1: Number of electrical cars (electricity and electrical hybrids) being registered, development since January 2006

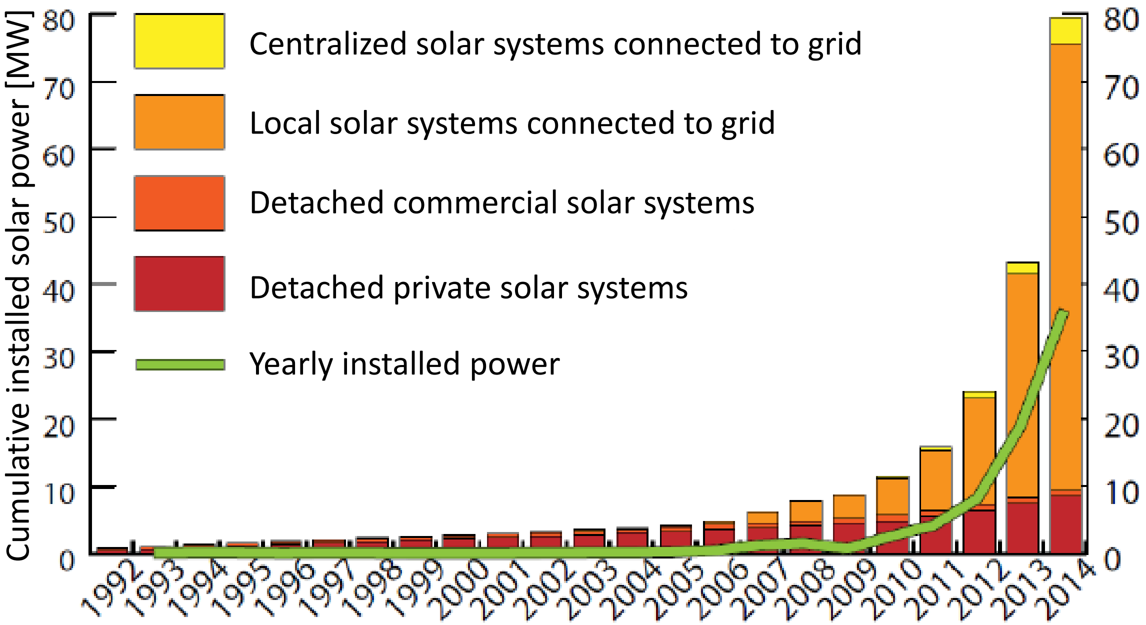


Source: Trafikanalys

Figure 6-2 shows the development of installed solar power in Sweden. As can be seen from the figure, the installed capacity has increased during recent years. It has continued to increase 2015 and 2016, driven both by the decreased technical costs for procurement and by the political incentives described in Chapter 6.1.4.

As can be seen from the figure, grid connected local solar systems accounts for the main part. These are mainly located at the roof of private houses (villas). As mentioned above, solar panels are also growing within the commercial segment. This is both due to the tax incentives described in Chapter 6.1.4 and due to companies wanting to have a green profile towards their customers.

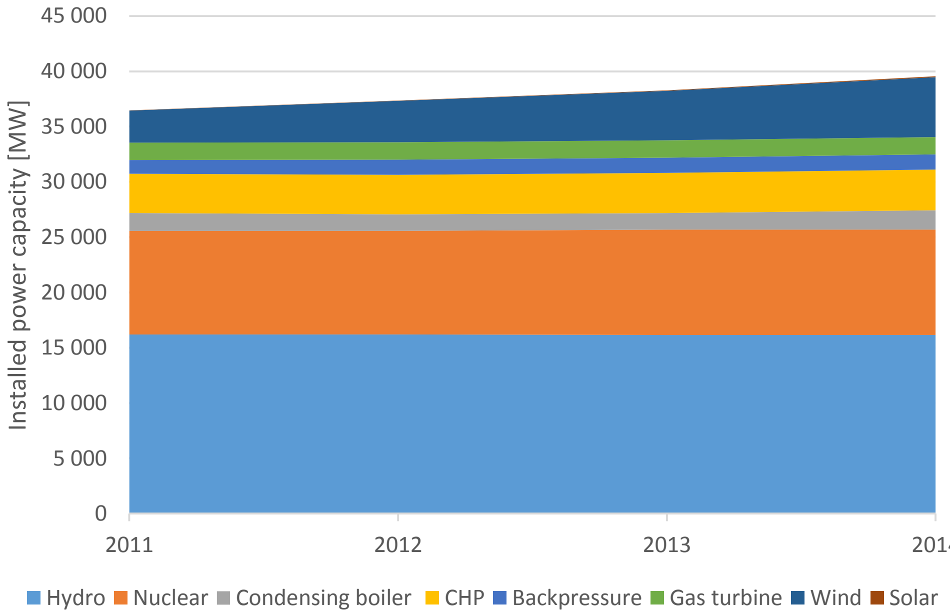
Figure 6-2: Installed solar power in Sweden 1992-2014



Source: Swedish Energy Agency

The total installed solar capacity is expected to continue to grow, but from very low levels. As can be seen from Figure 6-3, the installed capacity of solar (2014) was so low compared to the other types of installed capacity that is it not even visible in the graph. The installed solar capacity was 79 out of a total 39 549 MW 2014, accounting for approximately 0.2 percent of total installed capacity.

Figure 6-3: Development of installed power capacity in Sweden, different types of power generation



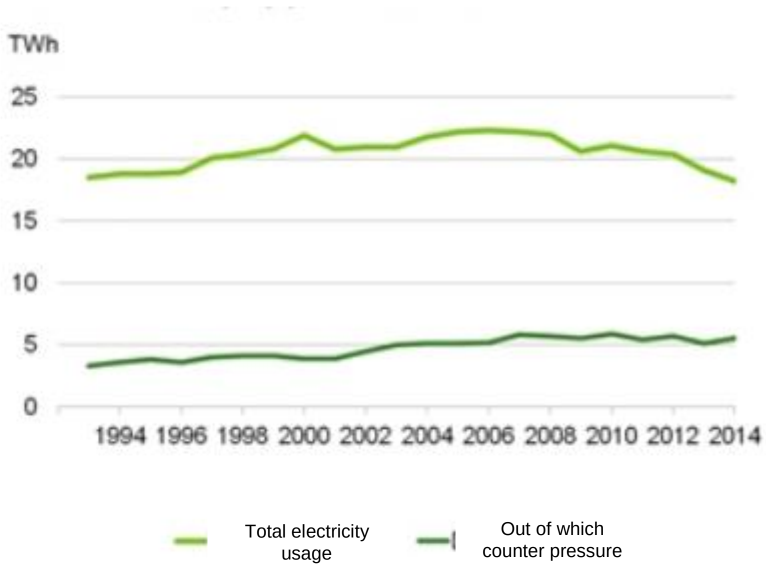
Source: Swedish Energy Agency

6.1.3 Industry DER

Some industries in Sweden produce their own electric power behind the meter. This has been the case for a long time. Such self-supply is free of power and distribution charges. However, electricity prices for industry in Sweden is low and the reason for self-supply is usually the requirement for process steam and to some extent due to a surplus of suitable waste fuels (mainly pulp and paper industry). The generated electricity is used either in their own processes or fed into the grid. CHP within the industry, where process steam is e.g. used for drying, is called industrial backpressure. In Sweden the pulp and paper industry is a very large energy consumer and this industry is the dominating one when it comes to producing its own electricity. Electric power is generated from both combustion of black liquor and from combustion of bark in boilers, which enables both back-pressure and condensing turbines. The pulp and paper industry accounts for 93 percent of the total backpressure-based electric power generation in Sweden. They receive green electricity certificates when they generate electric power (based on bio fuels), corresponding to approximately 16 öre/kWh. Industry sectors with a wide use of backpressure based electric power generation include the iron- and steel industry as well as the chemical industry. In 2015, backpressure based electric power corresponding to 5.9 TWh was generated accounting for almost 4 percent of Sweden's power production. The share of self-generated power generation can vary from a small amount up to a point where the industry is a net power producer (especially chemical pulp industry without own paper production). For example the large Steel industry SSAB in Oxelösund covers 50 percent of their power usage from their own production. Another example is the large forest company Södra that generates 1.8 TWh electric power per year, which covers their total demand and a surplus which is sold through their own electricity retail company. A modern pulp mill sells approximately as much electricity as it consumes (i.e. 50 percent of its electricity generation is used in the mill and 50 percent is excess electricity which is fed into the grid), but it varies.

Figure 6-4 shows development of total energy usage and backpressure within the paper and pulp industry.

Figure 6-4: Development of total energy usage and backpressure within the pulp and paper industry



Source: Skogsägarna

The paper industry has today approximately 30 percent of its total electricity usage from DER production.

Most of the companies have their power generation completely linked to their core process and have thus limited possibilities to shift their generation over time. Usually the generation is optimized foremost after heat demand in process. However, in some cases there can be optimization in regard to network power outtake, spot price and balancing power.

It should be noted that industry in Sweden pay much lower electricity tax than other companies and households, 0.5 öre/kWh instead of approximately 50 öre/kWh. The limit for not having to pay tax is at around 200 000 kWh per year (based on installed capacity and different for different generation techniques), and many industries exceeds this. Hence, their incentives for DER behind the meter is not as strong as for other stakeholders. As mentioned above they can – like all renewable producers – receive green certificates if their behind the meter electricity production is renewables (such as bio fuel).

Additionally, a limited amount of energy users have invested in DER for supply reliability reasons. These include hospitals, data centers, larger banks and some larger industries. These have reserve capacity (production or batteries). The most common is to have UPS, which enables controlled shut down of electrical equipment.

The production behind the meter is usually not reported to the balance settlement system. The Swedish TSO Svk therefore only sees the net feed-in value (if the generation is larger than the usage), and not the generation which is consumed behind the meter. The Swedish TSO Svk therefore uses a standard value to approximate the behind-meter-generation. According to the TSO the result is that both the generation and the usage behind the meter is underestimated.

6.1.4 Incentives for DER in Sweden

DER is politically encouraged in Sweden and there are multiple support systems and tax exemptions in place to create incentives for DER. Most of these target distributed generation. Even though most of the incentives target all kinds of small scale renewable production, in practice this has in principle mainly led to the installation of small-scale solar production units.

There are currently a number of governmental supports systems and exceptions for different DERs in place. For small-scale electricity production:

- Investment support for solar production
- Tax deduction for households for instalment of DER (lower labor cost). Cannot be received if investment support is received
- Exceptions from electricity tax (when using own-produced electricity), additional tax deductions (when feed-in)
- Reduced network cost for small scale producers (not only renewables)
- Electricity certificates (for all renewable production, also large-scale)

For energy storage:

- Support for electricity storage

For EVs:

- Support for procurement of electric vehicles (super-environmental-car premium) and support for electric buses
- Reduced taxable benefit for environmental cars (inc EVs)
- Differentiated vehicle tax depending on CO2 emissions and exemptions from vehicle tax during 5 years

  It is also under investigation whether a system should be introduced were cars with low environmental performance pay more and these proceeds are used to provide additional support to cars with better environmental performance.

These different incentives are described in the following sections. The electricity certificates are not specifically developed for DER and are therefore described in the background section (Chapter 4.1). However, some related lessons learned are described in this chapter.

6.1.4.1 Investment support for solar production

Since 2009 an investment support scheme is in place for solar panels. This support mechanism was meant to be valid for solar production installed between 1st of July 2009 until 31st of December 2016. In 2015 the Government however extended the support scheme until 2019. All types of actors can apply for the support funding: companies, organizations as well as households. The solar production does not need to be DER, it can also be large-scale solar production.

The total amount of possible support (since 1 January 2015) is 30 percent of the investment for companies and up to 20 percent for others. This is however only up to maximum 1.2 million SEK in support and the costs for installing the PVSs may not exceed 37 000 SEK.

6.1.4.2 Tax deduction for households for instalment of DER (lower labor cost)

It is possible for households to apply for tax deductions for the installation of PVs. For 2016 the deduction level is 30 percent of the work cost. It is not possible to receive both investment support and tax deduction for the labor cost.

6.1.4.3 Exemptions from electricity tax when using own-produced electricity

Most energy users in Sweden pay 29.2 öre/kWh in electricity tax. Industrial users pays 0.5 öre/kWh and users in the north of Sweden pay 19.3 öre/kWh (regional support). Renewable micro production of electricity for net users with a yearly production approximately below 200 000 kWh per year do not have to pay electricity tax for the electricity they use themselves. The exception is valid for different levels of installed capacity depending of type of electricity:

- The general level is 50 KW (must be renewable)
- For wind- and wave power it is 125 kW
- For solar power it is 255 kW

These levels are meant to correspond to a yearly production of approximately 200 000 kWh per year. It is a requirement that the electricity is both produced and consumed “behind the meter” (net user during one hour). If it is fed-in to the grid, see below. It is mainly users who otherwise would pay the higher electricity tax which have incentives from this exemption. In addition, the DER owner is not obligated to pay VAT (25% of total electricity bill) during hours of self-usage.

6.1.4.4 Additional tax deductions during hours of feed-in

Since the 1st of January 2015 micro producers of renewable electricity get an additional tax deduction of 60 öre/kWh during hours of feed-in. All stakeholders – companies, households and organizations – can receive the support, however the actors are required to be net consumers and to have a fuse size of maximum 100 A. It is also a requirement that the micro production facility has the same connection point, meter and fuse as the power outtake. Maximum 18,000 SEK per year can be received, corresponding to 30,000 kWh of feed-in during a year. The support proceeds are settled through an annual tax return (deduction of income).

6.1.4.5 Reduced network cost for small scale producers (not only renewables)

Small-scale electricity production in Sweden today pays reduced installation costs and feed-in tariff on the grid. This is mainly done for administrative purposes, even if it also to be seen as something which will lower the barriers to more people to invest in their own small-scale production. The exemption corresponds to approximately 3-4 öre/kWh, even if this can vary between net operators and type of installations.

6.1.4.6 Non-governmental compensation

In Sweden every energy user is free to choose their own electricity supplier. There are multiple energy suppliers offering good deals for DER owners (mainly small-scale producers of solar power), such as paying for parts of the investment, offering a lower electricity price, exemption from fixed fee and/or paying well for the electricity which is fed onto the grid.

Also the electricity grid company is usually paying the DER owner (mainly small-scale producers of solar power) for feed-in of electricity to the grid. However, one cannot choose grid company and the conditions varies.

6.1.4.7 Support for storage

The Government have allocated 25 MSEK for 2016 and 50 MSEK per year 2017-2019 in support for energy storage in households, in order to better enable households to store their self-produced electricity. They have stated in an official letter that technically this mainly will include batteries and battery systems. The investment support is given as part of the support within the micro solar production support (6.1.4.1). There is today no possibility to receive support only for energy storage.

6.1.4.8 Support for procurement of electric vehicles (super-environmental-car premium) and support for electric buses

Since 2012 there is a support for procurement of cars with high environmental performance. It is mainly electric hybrid or electric vehicles receiving the support. For an electric hybrid vehicle the support is maximum 25,000 SEK, whilst it is maximum 40,000 SEK for a purely electric vehicle.[5]

It is also possible to apply for support for investments in electric buses. The Government is allocating 50 MSEK during 2016 and 100 MSEK 2017-2019 for this purpose. Buses which run on 100 percent electricity are proposed to receive 300,000-700,000 SEK in support whilst electric hybrids get a bit less. The support will be possible to apply for during second half on 2016.[6]

6.1.4.9 Reduced taxable benefit for environmental cars (including EVs)

For electric hybrids or fully electric vehicles the taxable benefit value of the car is adjusted down to the value of a similar car without the environment performance. After that, 40 percent of this value is

[5] https://www.transportstyrelsen.se/sv/vagtrafik/Fordon/Supermiljobilspremie/

[6] http://www.energimyndigheten.se/klimat--miljo/fossilfria-transporter/elbusspremie/

reduced, maximum 16,000 SEK. The rules are applicable until end of 2016. It has been suggested that it is prolonged 3 years, however with a reduced maximum value (10 000 SEK).[7]

In Sweden the absolute majority of new cars entering the market is through company cars. Hence, the taxable benefit value has a large influence. Many EVs (like Tesla) are still (after reductions) far too expensive to be procured as company cars.

6.1.4.10 Differentiated vehicle tax depending on CO2 emissions and exemptions from vehicle tax during 5 years

Electric hybrids and fully electrical vehicles (as well as some other environmental friendly cars) have exemption from vehicle tax during the first five years of operation. The tax exemption is for the vehicle and valid for the first five years after a new car enter the market.

Also after five years the vehicle tax is lower for EVs than for gasoline or diesel fueled cars. Vehicle tax is determined based on vehicle fuels and emissions of carbon dioxide (CO_2). The tax has (simplified) two components:

- A fixed fee of 360 SEK/year
- A CO_2-fee of 22 SEK/gram for CO_2 emissions above 111 g/km when driving normal[8]

6.2 Lessons learned

Over recent years there have been a number of important lessons learnt regarding support schedules, taxes and exemptions for DER of which the most important are commented upon in the following sections. The initial one is about net metering and the reasons why Sweden – unlike many other countries – has chosen to implement an alternative to net metering.

6.2.1 Net metering

Net metering for micro producers of small-scale renewables is used in other countries and have also been discussed/tested by some grid companies in Sweden. Net metering means that the amount of electricity an energy client produces and transmits to the grid over a period is offset against the amount received from the grid during the same period. A governmental investigation drew the conclusions that net metering is against the EU's VAT directive. A text excerpt from this investigation is shown in Figure 6-5. However, the system is in use in other EU member countries today (who had made a different assessment).

[7] https://www.skatteverket.se/privat/sjalvservice/svarpavanligafragor/inkomstavtjanst/privattjansteinkomsterfaq/jagharenmiljobilsomformansbilhurberaknasformansvardet.5.dfe345a107ebcc9baf800019882.html

[8] https://www.skatteverket.se/privat/skatter/biltrafik/fordonsskatt.4.18e1b10334ebe8bc80003864.html

Figure 6-5: Text excerpt from a governmental investigation carried out 2013 looking at net metering (net debiting) and its alternatives (to facilitate for renewable micro production)

> The Government wants to make it easier for individuals who wish to set up micro-production facilities and whose primary aim is to make use of the electricity they produce. This will be accomplished by augmenting the opportunities for these individuals to sell their surplus electricity, or alternatively to enter into net debiting agreements.
>
> In the Inquiry’s view, a net debiting system would conflict with the Value Added Tax Directive. In addition, the Inquiry does not see any way to make use of any of the exemptions listed in the Value Added Tax Directive in this kind of system. Our conclusion therefore is that a net debiting system should not be introduced. Instead, the Inquiry proposes that micro-producers be given a tax reduction that corresponds approximately to the amount the producer would have earned in a net debiting system. A tax reduction would not contravene the Value Added Tax Directive. The reduction would, however, be a financial compensation for the electricity these producers often feed into the electricity system without remuneration. It could also both encourage microproducers and act as an incentive for electricity trading companies or electricity network companies to give micro-producers remuneration for the green electricity they produce. In addition, policy work in the sector can help encourage electricity trading companies and electricity network companies to enter into agreements with micro-producers on remuneration for electricity that is fed into the system.
>
> A tax reduction will be given to micro-producers of renewable electricity with a fuse of at most 63 amperes. This threshold has been chosen so as to include as many as possible of those who merely supplement their electricity use with their own electricity production. At the same time, it will not include those who in principle are exclusively electricity producers. The tax reduction is based on the electricity that has been fed into the electricity network, if a corresponding amount of electricity has been bought back. The tax reduction will roughly correspond to electricity tax and value added tax. Based on the 2013 tax rates on electricity, this would mean about 60 öre per kilowatt hour. No more than 10 000 kilowatt hours per year is to be eligible for a tax reduction.

Source: The Government

In Sweden the electricity spot price is set per hour (even though most costumers pay the monthly average cost). Net metering has been criticized in Sweden since it means that electricity which is fed onto the grid during one hour can have another market value than the electricity it is offset against during another hour. It has therefore been argued in Sweden that net metering removes the price signals and the incentives for demand response. On the other side, some have argued that net metering is simpler for all stakeholders involved.

As written in the text excerpt in Figure 6-5, the tax exemption during hours of self-usage together with the additional tax deduction of 60 öre/kWh during hours of feed-in has been implemented as an alternative to net metering, since it corresponds to approximately the same tax saving:

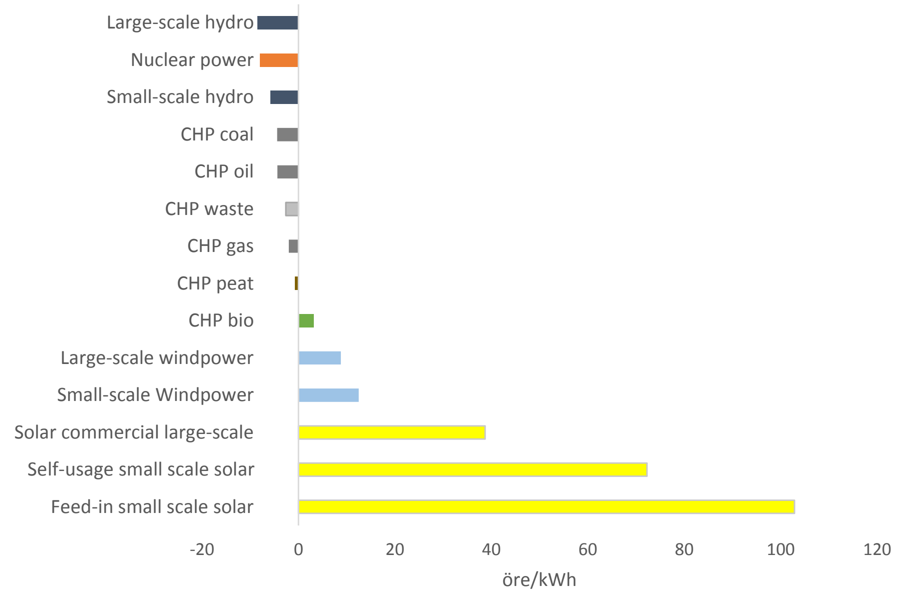
Electricity tax approximately 30 öre/kWh + VAT 25 % of total electricity price approximately 30 öre/kWh = the offered tax reduction of 60 öre/kWh

Please note that it is a coincidence that both the electricity tax and the VAT is approximately 30 öre/kWh. In this way the tax incentives (including VAT) are as strong as if Sweden has net metering, but the value of bough electricity is allowed to shift between hours.

6.2.2 Effects from taxes, support schemes and exemptions

There are multiple lessons learned from Sweden’s current taxes, subsidies and exemptions. Figure 6-6 shows the net effect from the governmentally added taxes, subsidies and exemptions for different power generation types in Sweden. As can be seen from the figure, different electricity generation types in Sweden has very different incentives (from the government). The two largest production types, hydro and nuclear, pays the most whilst especially micro production from solar is heavily subsidized.

Figure 6-6: Net effect from taxes, subsidies and exemptions



Source: Sweco

Electricity certificates

Electricity certificates mainly target large-scale renewables and lessons learned from it is therefore only briefly described here.

The electricity certificate system is constructed to phase in a pre-determined amount of renewables into the system, in which the most cost-effective renewables mainly will be chosen. This is cost effective. However, it mainly creates incentives for relatively mature technologies rather than those at an earlier development stage. Overall Sweden is pleased with its choice of RES support system, even if many actors would like to have no RES support system at all.

The fact that the support is related to produced kWh rather that capacity provided does not create incentives for renewable producers to provide capacity when needed (but rather to maximize production during a year). The reason for this is that the support is given based on installed capacity and not based on produced kWh.

It is also quite difficult for owners of DER to take part in the electricity certificate system since the certificate system is quite complex and administratively cumbersome.

Investment support for micro solar production

The investment support has been popular and has helped to promote the interest for solar production in Sweden. However, also other incentives such as tax exceptions has had an effect and it is hard to say what additional effect the investment support has created. A support scheme can help overcome financing obstacles. However, there is a risk of start-stop-problem, meaning that the market acts when there is support to be received and halters when the investment support temporarily run out of funding (which has happened several times in Sweden). Another risk is the fact that the investment support is unlinked to production, which does not increase the incentive to locate the production where it is most effective (i.e. where it produces the most electricity).

Support to solar production promotes a type of electricity production which peaks during summer and which has very low production during times when the demand peaks (winter in Sweden). Hence, the support scheme is not contributing to cope with capacity issues during critical times of the year.

The Energy Agency has suggested (late 2015) that the support system is removed, since the current tax reductions provide enough incentives for additional growth in small-scale solar systems.

Exemption from taxes for small-scale renewable DER

From a tax perspective small-scale production has stronger incentives than large scale renewables in Sweden today (see Figure 6-6). From a socio-economic perspective it is quite unclear why the small scale production should be favored over large-scale production. There is however a political interest to increase small scale-production.

Small- scale production on Sweden today is mainly solar production. As mentioned above this peaks during hours when load is relatively low (summer). So also this can be questioned from a socio-economic perspective.

Complexity of solar support schemes

Even if small-scale renewable production in Sweden has a lot of financial incentives, many stakeholders argue that there are too many different support schemes and exemptions, that it is too complex to be considered as a genuine supporting mechanisms by potential micro producers, especially taking into account the extensive application processes. Some argue that net metering would have been easier. They also argue that the current system does not send the right signals by for example paying back the tax savings (from feed-in of renewable on the grid, 6.1.4.4) only once a year, rather than continuously.

Incentives for environmental friendly cars

The high initial cost is the greatest barrier for many potential EV owners. Bringing the cost closer to that of a conventional vehicle would decrease this. Reducing the personal income tax for users of company cars is another way in which this cost can be decreased. Schemes should have clear goals and caps, with sufficient budget allocated in the case of subsidies. It is important to target the company cars, since these account for the major part of new cars in Sweden today.

Infrastructure needs to be available in urban areas and residential buildings so that users do not experience too great an inconvenience in recharging their vehicles. Charging infrastructure for EVs must be supported and developed, which is obvious from the lessons learned from the Nordics and other regions.

Another identified area to develop further in order to create additional incentives for EVs is to offer tangible benefits to owners of EVs, such as use of bus lanes, free parking, and free charging in urban areas. The ability to save time in urban areas during peak hours and increasing convenience for EV drivers are instrumental for encouraging the paradigm shift to EVs and increasing market growth.

6.2.3 Price areas and the role of regional planning

Because of the market design, there is very little regional planning of power generation in Sweden. There is no limit to how much DER can be introduced in a geographical area, the network company is obligated to connect all power generation. For small DER, there are even regulations saying that the connection fee should be reduced or zero (depending on how small the DER is).

Overall it is not accepted in Sweden that authorities involve in electricity generation planning, even if the government historically have been involved both when the hydro power and the nuclear power was built. Today, the view is that the market should create the right incentives to locate power generation were its most appropriate. The role of authorities is to overcome market failures by using policy instruments, rather than manage the actual planning.

Regional planning is applied a bit more when it comes to power grid planning. There are approximately 170 network companies in Sweden. There are many cases where the local energy company (often owned by the municipality) co-operate in their planning of municipal development. However, there are also many cases when they do not have any contact at all and also when the municipality is counteracting the network company’s plan.

The same can be said to be the case for district heating, where the municipality sometimes is very involved in the planning and sometimes instead counteracts the district heating company’s plan.

6.3 Going forward

In this section the future of DER in Sweden – and its opportunities and challenges – is described. Their effect on the larger system is further described in Chapter 7.

6.3.1 Future development of DER

As mentioned in 6.1.1, DER in Sweden is currently only developed to a limited extent. The fastest growing DER is micro solar production and electric vehicles. The use of batteries and energy storage is today very low but this is expected to grow, especially in the form of batteries in electric vehicles.

There is an ongoing discussion about demand response and the role it could play in Sweden, yet there is not too much implemented at the household/commercial level except from demos. In order to harvest the full DR residential potential, investment in information and communication technologies (ICT) is necessary. Smart appliances, home automation and smart meters are the main instruments to tap this potential. ICT technology can facilitate the interoperability of smart devices. Interoperability will depend heavily on standardization of appliances and of the different communication protocols.

Demand response in the residential and commercial sector can be procured manually or automatically. Calculations for DR potentials are very much depending on the assumptions of procurement. If consumers have to react individually to price signals, potential for DR is very low. If appliances are remotely controlled, tremendous potential for flexibility is theoretically available, especially in demand shifting, e.g. in air conditioning systems.

6.3.2 Benefits and services from DER (going forward)

Sweco has identified three types of benefits with increased DER:

- Production closer to load, which reduces grid losses
- The possibility to include more renewables
- The possibility for DER to help balancing the system, especially DR

Production closer to load and reduced grid losses

Increased DER results in less power transferred higher up in the grid (i.e. at transmission grid level and regional grid level). Transfer of electricity is associated with grid losses. Hence, when less power is transferred in the grid the losses decrease. These losses otherwise have to be covered by the network operator. Previously, these losses were seen as “uncontrollable” by the network operator. The network operator could transfer the cost for losses to their customers and they had no incentives to reduce these except from a separate yearly efficiency requirement. However, now the regulation in Sweden has added a “quality incentive”. Simplified this can be said to divide the gain from reduced losses between the customers and the network operator, by allowing the network operator an increased revenue cap. The regulation with incentives for non-controllable costs has only been in force since 2016 and it is too early to see its effects yet. However, network operators have stated that the financial incentive is very low compared to other components of the regulation and that they therefore will prioritize other issues such as increased CAPEX and supply reliability.

The benefit to the grid from DER (reduced losses) is awarded by network companies through payments for feed-in of electricity to the grid (amount depends on network operator, but around a couple of öre/kWh). Increased DER can however also bring additional costs to the network operator. These are described further in Chapter 7.

Possibility to include more renewables

DER production is mainly renewables such as small scale solar production. Also, increased storage and DR can help reduce the need for fossil peak power and fossil balancing power.

Possibility for DER to help balancing the system

Increased DER creates new possibilities to optimize the overall system by allowing distribution systems to participate actively in the system operation and by allowing DER to participate actively in the distribution system management.

In order to harvest DR residential potential, investment in information and communication technologies (ICT) is necessary. Smart appliances, home automation and smart meters are the main instruments to tap this potential. ICT technology can facilitate the interoperability of smart devices. Interoperability will depend heavily on standardization of appliances and of the different communication protocols.

The service which DR could provide to the overall system is further described in Chapter 7.

6.3.3 Challenging consequences from the growth of DER

Distribution grids were traditionally designed as 'passive' networks, containing mainly loads. In such power systems, power flows are uni-directional, from the high voltage transmission grid to the loads in the lower voltage levels of the system. Increased penetration levels of DER transform distribution grids to 'active' systems which, together with loads, contain high shares of generators and energy storage devices. This new system structure implies bi-directional power flows between distribution and transmission systems, since distribution grids will export power at times when local generation exceeds consumption. This evolution brings higher complexity in the management of distribution systems. The main identified challenges with increased DER are:

- Distribution grids having to handle reversed flow (at times with large distributed production)
- Feed-in of distributed renewables sometimes dimensioning for the local grid (rather than the maximum load)
- Increased intermittent electricity production
- Decreased usage of grid infrastructure and large scaled generation (resulting in stranded assets)

Since there is still quite limited DER in Sweden today these negative effects have not been seen yet or only to a very limited extent. The possible implications these can have are further explained in Chapter 7. The last bullet – stranded assets – has not (yet) been a consequence for electricity grids in Sweden. However, there are some lessons learned from customers switching away from district heating in Sweden. This is described in Chapter 8. Also, the overcapacity of installed power generation (compared to demand) in Sweden and neighboring countries has resulted in low power prices, making some power generation facilities unprofitable.

7 Grid Modernization and the Utility of the Future

While the present regulation offers some incentives aiming at a more efficient operation of the grid, those incentives can arguably become stronger. The supply reliability regulation plays an important role in how network operators manage the grid, and partly due to this a high supply reliability has been achieved across most parts of the country. This effectively eliminates large part of the incentives of using DER for security of supply for common users.

But DER can to a varying extent benefit from the regulated remuneration for producers that lowers costs for the network operator. The network operators have a relatively large degree of freedom in deciding how this remuneration is designed, and can make sure that only techniques that can offer a predictable lowered cost are substantially rewarded. The same degree of freedom goes for consumption tariff design, where cost-reflectiveness is the key framework. But the dependency on the feeding grid tariff imposes a risk for the DSO with too extravagant tariff designs.

It is clear that different tariff designs impose varying incentives. Pure energy tariffs without time differentiation generally subsidize DER, especially small VRES, to an extent where a slippery slope (with higher prices for customers without DER) could be induced if those technologies becomes commonplace, whereas power tariffs and other capacity charges reward a behavior better aligned with lowered grid costs. A recommended fundamental change is to revise the current categorization of customers based on fuse size. A more adequate categorization

would be based on the actual consumption pattern and the associated costs for the DSO.

In the field of metering one major reforms have taken place recently; the hourly metering reform which stipulates hourly metering at the expense of the DSO for customers (<63 amp) with a retail contract based on hourly prices. While this could be expected to lead to more hourly price contracts, this has not been the case. A major barrier is the fact that the DSO can choose whether to settle a customer monthly or by the hour, as a monthly settled customer with an hourly price contract imposes a financial risk for the retailer leading to them not actively marketing hourly price products.

The regulation limits DSO to only purchase electricity to the extent to cover grid losses. This effectively hinders them from, by their own, invest in energy storage function. Although this service could in theory be procured from a third party.

New functionality requirements for new electricity meters have been proposed by the Energy Markets Inspectorate, These include near real-time metering an ability to meter bi-directional flows, to name a few. This could very well be needed in the future, where simulation have shown reversible flows in large parts of the distribution grid due to VRES.

Related to metering is the process of establishing a data-hub which stores customer-, facility- and structural data in a central database. As of today, privacy issues following the explosion of consumption data has not taken a large place in the debate. The major argument is rather that this data is needed for giving customers adequate and fast feedback on their behavior.

The Swedish market setup is currently imposing some barriers for increased flexibility and DER flexibility. These are primarily related to large bid sizes and strict activation rules, but arguably the most dominant factor is the fairly low volatility in the electricity price. Instead customers (especially household customers) with flexibility will rather contract an energy service provider which focuses on improving the heat comfort and energy efficiency. Therefore, even though their impact is expected to rise in the future, aggregators don’t play a large role in today’s system.

From a market perspective, it can be argued that DER flexibility optimally ought to be reflected in the day ahead market price. Other alternatives have various drawback in addition to undermining the confidence in the spot price to accurately reflecting the state of the system. It is therefore somewhat counter-productive that the greatest remuneration today is found in the regulating market.

7.1 Current Status

7.1.1 How the present DSO regulation affects DER

Since the DSOs act on a natural monopoly market, their revenues are regulated. According to the Swedish law on electricity, the fee that the DSOs charge their customers should be reasonable, objective and non-discriminating. As a consequence, the network tariff should relate to the actual costs for the DSO, it should in other words be cost-reflective. The aim of cost-reflectiveness is that the customers should be charged based on the actual costs they create for the DSO. Furthermore, a DSO is obliged to offer the same tariffs to all customers within a customer category in their concession area.

The regulated interest rate is dictated by the Weighted Average Cost of Capital (WACC), which is set once for a complete regulatory period spanning over 4 years. For the regulatory period of 2016-2019 a WACC of approximately 4.5 % has been established by the Energy Markets Inspectorate.

The distribution networks have traditionally been built with a "top-down" way of thinking, that is, the power comes from the higher voltage levels and only moves in one direction, downwards the grid topography. Although networks are often built masked they are operated radially with open points out of the grid. When there is production in these networks (single wind turbines, small hydro) the affected lines are often built and adapted accordingly. This method of individually adapting the lines will probably be inefficient with respect to DER, calling for a new way of thinking.

7.1.1.1 Incentive for efficient grid management

The Electricity Act was modified in 2014 as a result of the introduction of the EU energy efficiency directive and now includes the sentence regarding network tariffs: “they should be designed in a way that is consistent with the efficient use of the network and efficient generation and use of electricity." In addition, it states that the extent to which the network operations are conducted in a manner consistent with and contributes to the efficient use of the electricity grid should be considered when the revenue cap is established. Such an assessment may result in an increase or decrease in what is considered a reasonable return on capital.

Since the previous legislation and price regulation (Prior to 2014) lacked financial incentives for the DSO to engage in guiding their customers in an efficient manner since this would ultimately lead to a decreased revenue cap, the government decided on a new regulation on the revenue cap for network owners in September 4, 2014. These provisions were entered into force on 1 November 2014 and applied by the Inspectorate of grid fees that applies for the current regulatory period (2016-2019).

In the changed regulation operational costs has been split into so-called refractory and affect costs. During the first regulatory period (2012-2015) the Inspectorate has classified costs for network losses, costs for overhead networks, the costs of agency fees and the cost of so called “nätnyttoersättning” (– a remuneration to generators located in the grid whose generation leads to reduced costs for the network operator) as refractory costs.

For the second period (2016-2019) certain elements of the so-called refractory costs are no longer treated as refractory. This applies for e.g.:

- Costs for the feeding grid
- Electricity losses

One way to achieve lower distribution losses is to create a uniform load in the network and one tool to achieve this is to create network tariffs that economically encourage customers to change. The Inspectorate exemplifies with offering financial incentives such as time- differentiated network tariffs and DSM to facilitate change.

If a network owner can achieve a more even load in the boundary points (the grid’s connection points to the feeding grid) it may be said that the network owners use their networks more efficiently. In order to achieve a more even load it is therefore crucial to gain both the participation and involvement of the end-consumers.

More in detail, the new regulation offers two new incentives for the network owners related to loads and losses in the boundary points. These incentives can together amount for a maximum of 5 % of the total revenue cap.

The incentive relating to lowered losses in the grid (I_{losses}) is calculated by multiplying the change in network losses between the two regulatory periods and then multiplying with the projected average cost of losses per kWh for the coming regulatory period. This product is then factored with 0.5, implicitly meaning that half of the incentive is passed on to the end user in the shape of a lowered revenue cap for the network owner (and thus resulting in reduced tariffs), while the other half is passed on directly to the network company as increased profit. This incentive is bi-directional; it can either yield more profit for the network operator or result in a lowered revenue cap depending on how they perform.

Figure 7-1: DSO incentive for lowered grid losses.

$$I_{losses} = \left(\frac{L_A}{E_A} - \frac{L_B}{E_B}\right) \times E_B \times p_{losses} \times 0{,}5\ [SEK]$$

I_{losses}	= Incentive, lowered losses [SEK]
L	= Total amount of losses [kWh]
E	= Total energy passing into the grid [kWh]
p_{losses}	= Projected average cost of losses [SEK/kWh]
$index\ A$	= The previous regulatory period
$index\ B$	= The current regulatory period

Soruce: The Energy Markets Inspectorate

The incentive for a more even load in the grid (I_{load}) is calculated by taking into account the average load factor of the period (i.e. the average of the quota between the daily hourly peak load and daily average load), the change in costs for the feeding grid in relation to transferred energy and finally factored by the total transferred energy during the period. Similar to the allocating 0.5-factor in the previous incentive, the load factor (ranging from 1 in a grid with perfectly even load and closing in on 0 if the volatility is extremely large) will generally be in the vicinity of 0.7 - 0.8 in most Swedish grids, and thus letting the network operator keep 70-80 % of the avoided costs while the rest is distributed amongst the customers through lowered rates. This incentive is not bi-directional at the moment.

Figure 7-2: DSO incentive for even load in the grid.

$$I_{load} = Q_B \times \left(\frac{C_A}{E_A} - \frac{C_B}{E_B}\right) \times E_B[SEK]$$

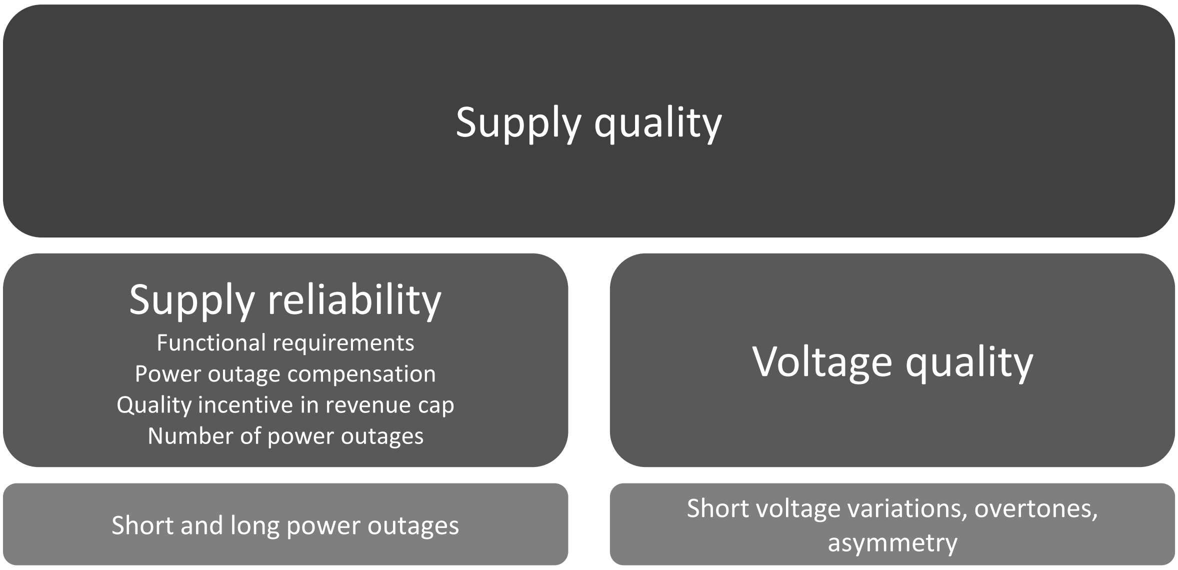
I_{load}	= Incentive, more even load [SEK]
Q	= Average load factor [-]
C	= Costs for feeding grid subscription [SEK]
E	= Total energy passing into the grid [kWh]
$index\ A$	= The previous regulatory period
$index\ B$	= The current regulatory period

Soruce: The Energy Markets Inspectorate

7.1.1.2 Supply reliability regulation

The term supply quality can be divided into supply reliability and voltage quality. This is shown in Figure 7-3.

Figure 7-3: Supply quality structure

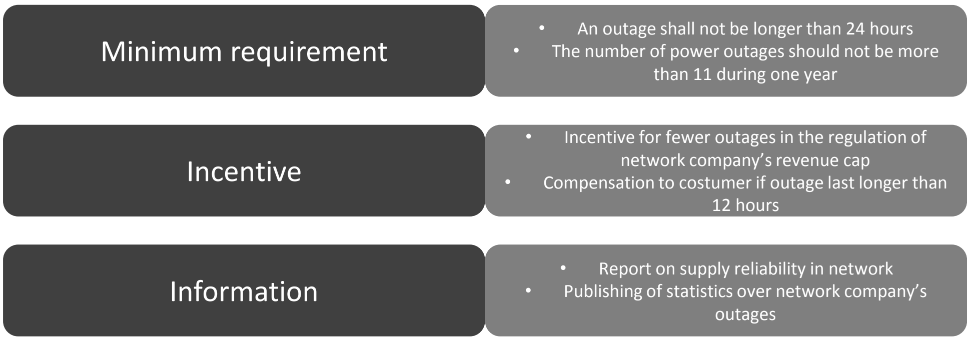


Source: Energy Markets Inspectorate

The voltage quality for normal customers should according to the regulation be within +/- percent of 230 voltages (during a 10 minute interval). The supply reliability regulation is a bit more complex.

The supply reliability regulations aims to set a lowest acceptable standard level (minimum), create incentives for the network company to improve beyond this level and to make sure than the customers get the information needed. This is shown in Figure 7-4.

Figure 7-4: Three types of measures to enable a good supply reliability



Source: Energy Markets Inspectorate

Some statistics regarding supply reliability in Sweden is shown in Table 7-1.

Table 7-1: Selected reliability supply data for Sweden 2013 and 2014

	2013	2014
Average power outage time	152 minutes	84 minutes
Number of power outages per customer	1.3 per customer	1.3 per customer
Percentage of customers with 0 power outages	-	Approximately 50%
Percentage of customers with 12 power outages or more	0.7%	0.9%
Percentage of customers with at least one power outage lasting at least 24 hours	1.4%	0.13%

Source: Energy Markets Inspectorate

The electricity law requires that electricity network operators limits their power outages to below 24 hours. The requirement is valid for everything within the network operator's so called control responsibility. These rules were implemented after the significant power outages resulting from the storms in Sweden in 2005, where many power lines were damaged by falling trees. The Energy Markets Inspectorate has not regulated the requirements for power lines in detail. Instead, they have a general requirement for tree safety enabling the network operator to be cost-efficient. Overhead lines with voltage above 25 kV, or power lines supplying power to other network operators' grids, should not be able to get interruption due to falling trees. Overhead lines from electricity production units producing electricity which are of importance for the grids operations shall also be free of potentially interfering trees. There are also additional requirements for loads above 2 MW, which are shown in the table below.

Table 7-2: Functional requirements for networks connected to customers above 2 MW

Load (MW)	Time of interruptions at normal recovery conditions (hours)	Time of interruptions during unusual recovery conditions (hours)
> 2 ≤ 5	12	24
> 5 ≤ 20	8	24
> 20 ≤ 50	2	24
> 50	2	12

Source: Energy Markets Inspectorate

The functional requirement of power outages to be below 24 hours is not valid if the network operator can show that the power outage not reasonably could have been foreseen or expected or if the consequences reasonably could not have been avoided. There are also functional requirements regarding maximum number of power outages per customer and year (11) and power quality.

Network operators in Sweden are required to pay a compensation fee to customers for power outages with a duration of more than 12 hours. The compensation is 12.5 percent of the annual calculated grid cost, but at least SEK 900 (Roughly equaling 100 EUR). The compensation increase stepwise with 25 percent units, or at least SEK 900, for each started 24-hour period. The maximum compensation is 300 percent of the annual grid cost. In order to get the network operators in Sweden to strive for an optimal delivery reliability from a socioeconomic perspective part of the energy distributors users' costs for power outages is internalized into the network operators' incentives. The part of a customer's power outage which is internalized as an increased or decreased revenue cap is the difference in power outage cost between "the standard level" and a corresponding company's level of reliability. An optimal level of increased or decreased revenue cap corresponds to the level in which the network operator's marginal cost to increase reliability is the same as the consumers marginal cost of power outages. The network operators will strive for optimal supply reliability level so that their earnings are maximized.

Regulators do not need to be aware of the network operators costs associated with increased supply reliability as long as the increase or decrease in revenue cap is put in relation to the cost of outages.

Since 2010 the network operators in Sweden have reported more detailed statistics regarding power outages, which enables the use of a more customer differentiated cost valuation which accounts for that different customers have different costs for power outages. Using a customer differentiated cost valuation provides better incentives for optimal supply reliability, since customer power outages cost are reconstructed with a higher accuracy. The different costs are shown in Table 7-3.

Table 7-3: Disruption cost estimate

	Not notified power outages		Notified power outages	
	Energy cost SEK/kWh	Power cost SEK/kW	Energy cost SEK/kWh	Power cost SEK/kW
Industry	71	23	70	22
Retail and service	148	62	135	41
Farms	44	8	26	3
Public sector	39	5	24	4
Households	2	1	2	0
Network connection points	66	24	61	18

Source: Energy Markets Inspectorate

Quality indicators are calculated before the regulatory period and then compared to the outcome after the regulatory period. The electricity network company will then receive either an increased or decreased revenue cap. The quality adjustment (up- or downward adjustment of the revenue cap) may not exceed 5 percent of the revenue cap. Also, the total deduction may not exceed the return on the capital base.

In Sweden the electricity network concessions are divided into area concessions and power line concessions. A company can have either area concession, power line concession or both The area concession is concession for local grid and all of Sweden's area is divided into different concession areas (i.e. at every given spot in Sweden only one company will have area concession). Higher voltages such as transmission, connection of large scale power producers and some industries/larger users instead has line concession, i.e. concession only for a specific power line.

For network concession in a network area the following quality indicators are applied:

- $CEMI_4$ (Customer Experiencing Multiple Interruptions): The proportion of customers (power outtake points) which has four or more unannounced power outages (between 3 minutes and 12 hours) during a year
- SAIDI (System Average Interruption Duration Index): Average interruption time for unannounced and announced power outages per customer type.
- SAIFI (System Average Interruption Frequency Index): Average interruption frequency for unannounced and announced power outages per customer type

For power line concession (including national grid (TSO)) the following quality indicators are applied:

- ILEffekt (Lost load): the calculated power in kW which would have been supplied if there was no power outage.
- ILE (Lost energy): The calculated amount of energy in kWh which would have been delivered if there was no power outage.

The Energy Market Inspectorate calculates the average value for each quality indicator. Those network companies that have poorer quality indicator numbers than the average gets the average value as their norm value. However, the companies that performed better than average (i.e. their quality indicators values are better than the average ones) will have their own historical quality indicators as norm value.

Calculation of quality adjustments for network concession in a network area (Each network company's SAIDI, SAIFI and $CEMI_4$ is compared to its norm value):

- SAIDI Quality cost: The difference between the norm value and the yearly outcome (measured in minutes but recalculated to hours) of SAIDI is multiplied by yearly average load (yearly average supplied power in kW) and multiplied with the power outage cost value in SEK/kWh (showed in Table 7-3). This is done per customer type for both announced and unannounced power outages.
  Quality $cost_{SAIDI}$ = ($SAIDI_{actual}$ – $SAIDI_{norm}$) * yealy average load * the power outage cost value in kWh
- SAIFI Quality cost: The difference between the norm value and the yearly outcome of SAIFI (number of power outages) is multiplied by yearly average load (yearly average supplied power in kW) and multiplied with the power outage cost value in SEK/kW (showed

in Table 7-3). This is done per customer type for both announced and unannounced power outages.
Quality $cost_{SAIFI}$ = ($SAIFI_{actual}$ – $SAIFI_{norm}$) * yealy average load * the power outage cost value in kW

- $CEMI_4$ Quality cost: The actual $CEMI_4$ is compared to the $CEMI_4$-norm value to see if an additional adjustment should be made. An adjustment is made given one of these circumstances:
    1. The difference ($CEMI_{4norm}$ - $CEMI_{4actual}$) is negative when at the same time the quality cost is positive. In this case, the supplement should be reduced by (1-abs($CEMI_{4norm}$- $CEMI_{4actual}$))
    2. The difference ($CEMI_{4norm}$ - $CEMI_{4actual}$) is positive when at the same time the quality cost is negative. In this case, the deduction should be reduced by (1-abs($CEMI_{4norm}$- $CEMI_{4actual}$))

  Regardless of 1 and 2 the adjustment from $CEMI_4$ should not exceed 25 percent of the yearly quality cost.

Calculation of quality adjustments for network concession for power line concession (including national grid, the TSO) (Each network company's ILE and ILEffekt is compared to its norm value):

- ILE Quality cost: The difference between the norm value and the yearly outcome of ILE (lost energy) in kWh and multiplied by the power outage cost value in SEK/kWh (showed in Table 7-3). This is done per customer type for both announced and unannounced power outages.

Quality $cost_{ILE}$ = (ILE_{actual} – ILE_{norm}) * the power outage cost value in kWh

- ILEffekt Quality cost: The difference between the norm value and the yearly outcome of ILEffekt (lost load) in kW and multiplied by the power outage cost value in SEK/kW (showed in Table 7-3). This is done per customer type for both announced and unannounced power outages.

Quality $cost_{ILEffekt}$ = ($ILEffekt_{actual}$ – $ILEffekt_{norm}$) * the power outage cost value in kW

The quality costs for each network company are summarized into a annual quality cost, which can be either positive or negative. When calculating the increase or decrease in revenue cap the total annual quality costs are summarized for the full four year regulatory period.

7.1.1.3 New method for calculating depreciation for CAPEX

A significant part of the network owner's expenses consist of cost for capital investment in network facilities, such as lines and substations. Such investments are often large, while they have long economic lives, which means they are subject to depreciation. For the calculation of depreciation, the Energy markets Inspectorate has during the regulatory period 2012 - 2015 applied the real annuity method, providing a constant annual cost, annuity, for depreciation of capital investment. A number of problems during the period was observed and a selection of those considered relevant for the study are presented below.

If a facility's actual life span exceeds the financial one the network owner gets full compensation with the same annuity for the years in between. This leads to CAPEX investments being overcompensated, which is paid for by the users through a higher revenue cap. Network owners thus have an incentive to make their existing facilities operate as long as possible. For such measures which extends the lifetime of network components the network operator can receive the same revenue as previously, although the network owner's costs of these measures may be significantly lower. To maintain the quality of the electricity grid, which will thus consist of aging facilities, EI has used a quality control regulation that takes into account, among other things, the security of supply for determining the revenue cap. Though, this has not resulted in sufficient impact, since the negative impacts of poor security of supply falls short of the costs of quality improvements.

After suggestions from Energy Inspectorate, real linear method is used for calculating depreciation during the next regulatory period. This means that capital costs gradually decrease over the life span of the investment and will reach zero at a predetermined age. Energy Inspectorate argues that the declining reimbursement provide increased incentives for new investment in the network for more efficient components. But the trade association Swedish Energy argues that the societal profitability to replace functioning facilities are dubious and classified as waste. Instead, the Energy Markets Inspectorate believes that the profits of operating a well-functioning component longer than the economic life span only benefits the network owners, while consumers are forced to pay the same fee as if the facilities were new.

7.1.1.4 Network tariffs

Sweden's current regulatory situation contains few limits to tariff design, which enables utilities to adjust accordingly. The Energy Markets Inspectorate doesn't conduct any active monitoring of the tariff design that network operator's use, for that to happen it takes either an individual customer complaint or in conjunction with a network operator filing a request to the Inspectorate for modifying or using a new tariff setup.

The Electricity Act outlines a couple of governing principles regarding tariff design:

- Reasonability – dictates the aggregated cost level of the tariff and is therefore tightly connected to which costs the network operator can pass forward to the customer, i.e. the revenue cap.
- Objectivity - aims to achieve a correct cost distribution between customer categories. It is therefore prohibited to favor one customer group at the expense of others. The tariff should be designed in the same way for all customers in the same customer category. The principle of objectivity of often related to the term "cost reflectiveness".
- Non-discrimination – states that a network operator isn't allowed to favor one customer before another based on e.g. if they buy their electricity from an electricity retailer within the same company group.
- Localization – a network operator is not allowed to charge two similar customers differently on the sole basis that they are situated in different geographical parts of the grid.

A more unspoken principle applied by network operators is "simplicity" in the tariff design to the extent that tariffs should are comprehensible for the average customer.

The aim with cost-reflectiveness is for each customer-type to carry their own costs, at the same time as the customers are presented with correct incentives. But in today's reality the phenomena of "swings and roundabouts" is more or less prevalent. This stems from the use of "fuse-subscriptions", which has been deemed as the most cost-reflective way to charge low-voltage customers (<63 amps fuse) when only monthly energy values and size of the customer's fuse are available.

In a fuse-tariff a customer typically pays a fixed fee as well as variable energy-cost. The fixed fee have been differentiated based on the size of the customer's fuse, the customers have in others word been paying for the *option* to use a certain amount of power, disregarding the time-aspect.

Table 7-4: Template fuse subscription

	Apartment	16 A	20 A	25 A	35 A	50 A	63 A
Fixed fee [EUR/a]	55	110	160	200	270	390	520
Energy fee [cents/kWh]	24.5						

Source: Sweco

Based on this network tariff structure, less transmitted energy renders lowered income for the utility company. This would lead utility companies having to raise the cost levels in the whole tariff in order to compensate for the loss of income since the cost side in the short term remains unchanged. Likewise, large but temporary power consumption is not costly for the customer but more so for the network operator. This reasoning motivates a transfer in tariff structures towards one that is to a larger extent based on the real cost drivers for utilities.

For some time, several parallel discussions regarding the use of the local distribution-grids and necessary changes in the network tariffs for low-voltage customers, have been taking place. Actors ranging from the European organizations Eurelectric, GEODE and ACER to the Nordic organization

North European Power Perspective (NEPP) and the Nordic Energy regulators (NordREG) have all highlighted this area as important to facilitate the future power system. The main drivers for these discussions are both the hourly metering and settlement reform as well as the changes in the power system with an increasing share of VRES, which will present the electricity-suppliers and network operators with new challenges.

Some network operators have already taken the step to introduce new network tariffs and many others are on their way of doing so. Alternate tariffs available today include various ToU-schemes and power-tariffs (SEK/kW) where the cost-driving peak is made up from either a single maximum peak to the average of the maximum 2 or 3 peaks. The future trend for network tariffs will probably be influenced by the recent recommendations made by the trade organization Swedish Energy for a monthly power tariff (SEK/kW) which (in similarity to the current fuse subscription) also has an energy component and fixed fee.

As a change in tariff design is a large readjustment for network operator it is natural to feel the need for conducting pilot studies involving only a few customers. However, given the current regulation this is not allowed. The utility E.ON. experienced this when they filed a request for exemption from the principles of objectivity and non-discrimination to try out an alternate tariff for eight apartment customers which was rejected by the Inspectorate as there was no legal support to do this.

Although the total revenues of the Swedish network operators are regulated, levels of the cost components in the tariff are always adjustable. But every single change should to be communicated to the customer, resulting in extra work for the DSOs, and can also be perceived as negative by the customer. From a customer-perspective it is also important that the network tariffs are transparent and fair, which promotes a future harmonization of their appearances.

Producers with <43.5 kW connected power is treated as micro-producers. By law, the customer can connect their generation facility to the grid without extra costs if the customer is already connected to the grid. But the customer needs to report to the network operator if they are about to install a small generation facility (In practice this is most often done by the electrician that connects the facility). As long as the customer on an annual basis is a net consumer no extra charge for a generation network tariff applies. Also, the network operator is only permitted to charge producers with 43.5<X<1500 kW connected power an administrative fee, thus exempting them from other OPEX as well as CAPEX they cause. These costs are then socialized across the customer collective in the concessional area. Both of these exceptions for network tariffs benefit small generating facilities.

7.1.1.5 Remuneration to producers contributing to benefits for the network operator

All producers are given two types of "remunerations" from the network operator ("nätnytta"), one based on the electricity produced and symbolizes the DSOs reduced costs for lowering their energy outtake from the feeding grid, and the other is a power-based remuneration which symbolizes the network operator's ability to lower their subscribed power from the feeding grid. The feeding grid is often the regional grid, and the tariff for this level of the grid is fairly similar across the country and is usually made up of the following components:

- Fixed fee – annual subscription
- Power fee – annual subscription based on the average peak load based on a various number of occasions
    - The regional network operator in the south of Sweden, E.ON, also applies a time differentiated power-fee
- Variable energy fee – with the same kWh cost across the whole year

Since network operators subscribe for a certain amount of power and is charged an extra fee (1.5 times the regular fee) if the subscription is exceeded, it is crucial for the network operator to be able to accurately estimate the dispatch from the production facility at times with high load in the grid if they are supposed to remunerate the producer. Hence, with micro VRES-production being intermittent, it is hard for a network operator to plan and capitalize on a "potential" reduction in load.

But in combination with some sort of storage technique, this mechanism might yield larger incentives for DER which feeds electricity out to the grid.

7.1.2 Regional and central grid transmission tariffs

As described in the previous chapter 7.1.1.5 the tariff design for the regional grid is composed of a fixed fee, power fee and variable energy fee. The reason for this design is the shape of the central grid tariff, which consists of a power fee and variable fee. The central grid tariff is somewhat locationally differentiated, but less so than it has been historically. This locational differentiation is due to a large generation capacity (hydropower) in the northern parts but where the consumption mainly takes place in the southern parts.

This setup can potentially induce risk for DSOs which opt for a tariff design which has discrepancies from the RSO tariff (i.e. their own cost structure).

7.1.3 Retailers and retail tariffs

The role of the retailer covers physical purchase of electricity from generators via bilateral agreements or the day ahead and intraday market as well as financial trading via futures and forwards. Retailers also have a responsibility to balance all their purchased electricity with the corresponding amount of consumption, something they often outsource to specialized BRPs due to economics of scale.

Following the implementation of the supplier centric model, retailers are supposed to be the only link to the electricity market a customer needs. All DSO billing to end users is going to pass through the retailer and customers will only need to contact the DSO in case of strictly grid-related questions such as outages and delivery performance etc..

Bilateral agreements is often arranged for large consumers, while the rest of the customer base face a transparent list price. The list price is generally made up of a cost per kWh which can be hedged for various lengths of time or it can be more or less connected to the hourly variations on the day ahead market. For a more complete picture the distribution of contract types, view chapter 5.1.5 Electricity supply contracts.

Since the first of January of 2015, electricity retailers are by law obliged to manage the electricity production from micro generation (<43.5 kW).

The power supply market in Sweden is competitive and companies search for ways to can offer other values than just low power prices, as well as ways to build a long-term-relationship with the consumers. Since 2012 more and more power retailers have started to promote small turnkey solar module systems. The size of these varies, but they are usually between 1.5-15 kW. The majority of power retailers cooperate with local Swedish installation companies which provide the solar system and install it. A few power retailers procures solar modules themselves and install these. By the end of 2015 there were around 20 power retailers in Sweden offering solar power module solutions to their customers.

A recent example of this is shown in Figure 7-5.

Figure 7-5: Example of how DER business model for retailer

> During March the Swedish medium sized utility Umeå Energy launched (as the first energy company) the possibility for household customers to lease (rent) solar panels. So far around 300 households have reported their interest in finding out more about the offer. The main part are located in the geographical area nearby the company Umeå Energy, but customers in other parts

Source: Energy Market Sweden business news

Sweco's assessment is that Umeå Energy (as well as other retailers offering solar power to their customers) is offering this service in order to tie the customers closer to them.

7.1.4 Metering and data as a facilitator for DER

7.1.4.1 Hourly metering reform

The Energy Markets Inspectorate found that a transition to the metering of electricity consumer's consumption per hour would improve the function of the electricity market. It was also found that the introduction of hourly metering for all electricity customers would be too costly. The assessment was that progress towards more hourly settlement for customers would best be done in a slow pace, based on customer -driven initiatives.

Of the country's approximately 5.3 million metering points, it is possible to implement hourly metering for 92 percent (4.876 million metering points), but only 42% of these points have hourly metering at the moment. To enable the collection of hourly data from all data points, adjustments in enhanced communication need to be made, e.g. upgrading of concentrators (i.e., a component of the metering system).

With the technological development in combination with regulatory demands, the access to hourly consumption-data is increasing. Since 2012 end-users which have signed a contract demanding hourly metering with their electricity supplier, is entitled to have a meter installed by the network operator (without extra costs for the individual end-consumer) which can handle those requirements. The Swedish Energy Markets Inspectorate have also issued functionality-demands on electricity-meters, which is expected to further increase the access to hourly consumption measurements.

It should be noted that the network operator already is obliged to hourly meter all high voltage customers (>63 amps fuse).

7.1.4.2 Functional requirements on electricity meters

The Energy Markets Inspectorate have specifically analyzed functional requirements aiming at easy access for customers to market price information, and therefore being able to respond to price signals in a more efficient way, as well as other features that promote a reliable and efficient network operation, reduced energy consumption and increased integration of local production.

One recommendation is that the customer gains free access to near real-time consumption and production values. This will promote energy efficiency through better visualization of the consumption (instant feedback), as well as allow for:

- DR based on the spot price
- DSM for balancing market via aggregator or for time-differentiated network tariffs
- Frequency regulation via TSO (especially important in the summertime with lots of wind production when the balancing with hydro is more expensive because of congestions issues)
- Better information for BRP to predict the load and to buy the appropriate amount of power. Approximately 25% lowered cost for the BRP may be possible.

Another recommendation is that the meter shall register voltage, current, energy and reactive as well as active power in both directions for each phase. This will keep abreast of the case of customers who decides to install a solar panel or other micro production, as the network operator needs a meter that can handle this. As this is more probable for house owners, the benefit of doing this is greater for these types of customers compared to apartment customers. This could pose an obstacle for the expansion of DER if not implemented since it make the business case for net production from DER less interesting if the excess can't be accounted for. It also facilitates:

- Ability for the network operator to gather grid voltage information and better predicting peak loads in parts of the grid.
- Metering of reactive power and possibility of including it in the tariff for low voltage customers if appropriate. As more applications is using large amounts of reactive power (LED-lights, heat pumps, inductions stoves, low energy lighting) this could be a potential problem in the future.

- Ability to control the power outtake on customer lever in times of situations of high loads in the grid.
- According to retailers, hourly settlement is a prerequisite for many products relating to DR and DSM. This demands hourly metering.

7.1.4.3 Data hub

A central data hub means an information management model where the customer-, facility- and structural data as well as all measured values are stored in a central database. The central system also includes functionality to manage several important processes of the electricity market directly into the hub.

Earlier investigations (e.g. NordREG report 3/2013) have pointed out a central data hub as the best long-term solution of data management. Our neighbors Denmark and Norway have already come to this conclusion for their respective markets. In Denmark, a data hub is in operation since March 1, 2013. In Norway a data hub is expected to be taken into operation in the autumn of 2016.

It is proposed that the consumer per default gains exclusive rights to their own data, but can commission other parties to access and use their data.

With the risk of the consumers consumption profile becoming available for hacking, privacy risks arise. It will for instance be possible to view in greater detail what appliances is in use (compare with the ability to separate customers with a heating load with monthly data) or if a house is empty. But if the customer operates DER (either a small production unit or an energy storage) the signal emitted through the meter will be “scrambled” in the sense that it is not only made up of the user’s consumption.

Overall, the discussion regarding privacy issues related to metering data is in it’s infancy in Sweden, and criticists are not given a lot of room in the debate.

7.1.5 Business development relating to DER in utilities

Several utilities in Sweden (Vattenfall, E.ON, Fortum), as well as retailers (Storuman Energi) and other private actors (Eliq) have started to offer what can be referred to as “diode meters”, which basically is a device that is mounted on top the existing meter and counts the light pulses emitted from the meter. This type of metering is gives the user access to real-time power data and continuous statistics, in contrast to regular metering which gives the customer access to the information at least a full day afterwards.

Today, customers with solar power sign contracts with utility companies that buy all surplus production. Utilities have begun marketing solar modules to the end-user market giving the customer a special deal of better remuneration from the surplus production if the customer buys the PV though that specific utility.

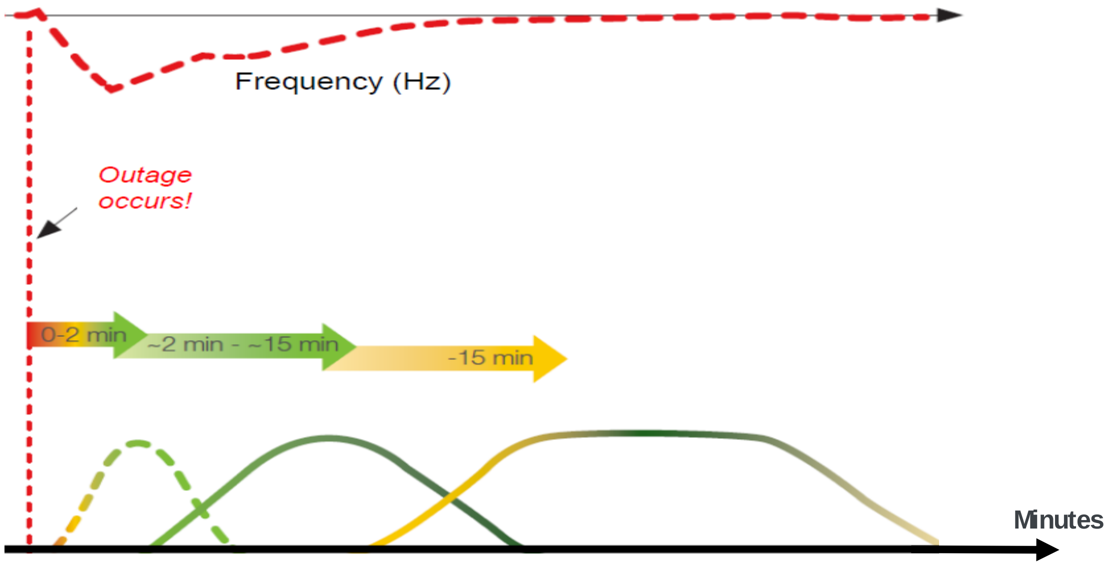
7.1.6 Microgrids

The presence of microgrids have traditionally been small in Sweden and this trend shows no sign of changing in the foreseeable future. Even though the country is sparsely populated at certain places connection to the grid if most often accessible not too far away.

7.1.7 Current marketplaces for flexibility and DER flexibility

Figure 7-6, which also was included in the Market design chapter (Chapter 4) shows an overview of current balancing services. The three different types of frequency control primary frequency control (Frequency Containment Reserves, FCR), secondary frequency control (Automatic Frequency Restoration Reserves, FRR-A) and tertiary frequency control (FRR-M, Manual Frequency Restoration Reserves) have different characteristics and different functional requirements.

Figure 7-6: Overview of current balancing services



Source: Sweco

Primary frequency control is automatic. It is divided into normal and disturbance, FCR-N & FCR-D. These products are paid as bid for the capacity part. An energy part is also paid during activation (the highest one of spot and balancing price). An overview of FCR is shown in Figure 7-7.

Figure 7-7: Overview of FCR (primary frequency control)

FCR

- Activated locally, triggered by frequency change (delta)
- Bids regarding FCR should be cost based, with some margins for profits and risks
- Capacity procurement and remuneration, energy remuneration according to regulating power price
- Bid size at least 0.1 MW/bid
- FCR-N and FCR-D procured at two different gate closures; D-2 & D-1
- D-2 –*two* days before delivery
- D-1 –*one* day before delivery
- FCR bids are accepted during one hour or more (block bids)
- Bids are bindning, but can be repurchased (using marginal price)

FCR-N

- Frequency 49,9-50,1 Hz
- 63% should be activated within 1 minute, 100% within 3 minutes

FCR-D

- Frequency 49,5-49,9 Hz
- 50% should be activated within 5 seconds and 100% within 30 seconds

Source: Svk

FRR-A was introduced in the Nordics in 2013 due to severely reduced frequency quality since the second half of the 90s. FRR-A is still under significant development. FRR-A is pre-qualified and then activated automatically when needed through activating signal. FRR-A is paid as bid for the capacity part. An energy part is also paid during activation (the highest one of spot and balancing price). An overview of FRR-A is shown in Figure 7-8.

Figure 7-8: Overview of FRR-A (secondary frequency control)

FRR-A

- Pre-qualification of regulating power objects
- Automatic activation through activation signal
- Capacity procurement and remuneration, energy remuneration according to regulating power price
- 100 % activation within 2 minutes
- Separate bids for up- and down regulation, volume in steps of 5 MW
- Bids are binding. If problems arise with the delivery SvK should be notified as soon as possible
- Bids on Thursday 10 am at latest, for next Saturday-Friday (week ahead)

Source: Svk

Figure 7-9 shows an overview of FRR-M. FRR-M is the manually activated frequency control. For each hour of delivery the bids are ranked (cheapest bid for Svk is called first, then the second cheapest etc). Marginal pricing is applied, i.e. each bid gets paid what the highest bid got paid (or has to pay the lowest price).

FRR-M can be activated both due to frequency reasons and grid reasons (when a transmission grid is overloaded). The bids do not need to be accepted in price order: the TSO (Svk) can accept a more expensive bid if it balances the system in a better way (for example by not increasing the strain on a specific part of the grid).

Figure 7-9: Overview of FRR-M (tertiary frequency control)

RR-M

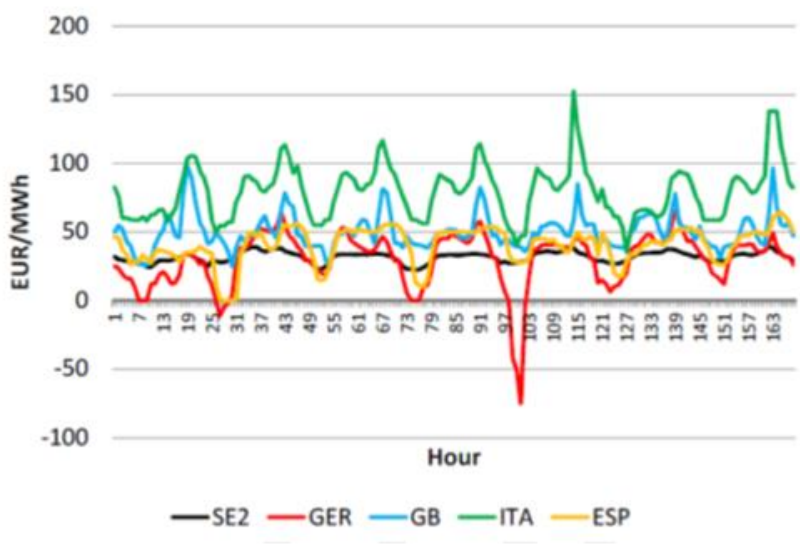
- Provision divided into generation and consumption
- Lowest volume in Swedish bidding zone 1, 2 and 3 is 10 MW, 5 MW in bidding zone 4
- Usage facilities within the same usage regulating power object should be located in the same bidding zone
- Remuneration by energy only
- Demand response regulating power objects should have a power offtake subscription of at least 50 MW
- If the activation time is less than 15 minutes the object should have real-time metering
- Bid can be revised up to 45 minutes before hour of delivery
- Bids adopted in Nordic ranking, marginal pricing
- Exceptions can be made if needed

Source: Svk

Generally speaking there are several barriers for both aggregators and DER. Market rules and product definitions are historically designed to fit with the needs of central generators. While there is a process of adjusting these to facilitate for new resource providers, there is more to be done. Regulating objects are divided into production- and usage objects. Each regulating object can only belong to one balance responsible. This hinders other aggregators (other than those balancing responsible for a specific facility) to aggregate multiple different facilities into a regulating object. Aggregators need to aggregate DER in order to participate on the balancing market since minimum bid levels apply. Minimum bid size and bid increments have been lowered. Currently in Sweden day-ahead market the threshold is 0.1 MW, which implies good possibilities for aggregators and DER participation. While such a decrease has taken place also in some balancing markets, minimum bid size and bid increments remain high in the balancing market. Bid size constitutes a barrier for DER market participation. As written above the bidding size for the manual bids (tertiary frequency control, FRR-M) is 10 MW in bidding zone 1, 2 and 3. It has recently been decreased to 5 MW in bidding zone 4 in order to enable other more sources of frequency control. Almost all frequency control in Sweden is hydro power, and this is mainly located in the North in price area 1 and 2. Furthermore, activation rules also have significant impact on the possibilities for demand side participation (see Figure 7-7, Figure 7-8 and Figure 7-9), and this impact need to be considered when defining such rules. As shows in the figures the activation time for manual bids are usually 15-45 minutes, whilst it is 5 seconds-2 minutes for automatic frequency control (primary and secondary frequency control).

Figure 7-10 shows hourly prices for an example week in different European countries. SE2 (hydro dominated price zone in Northern Sweden) shows an almost non-existent price variation within the day or over the week. The market value of flexibility in the day-ahead market is thus (very) limited. Of course there could be a value of being flexible on intra-day and balancing markets, but given the amount of easily regulated hydro power that value is also expected to be low. Local flexibility in distribution networks could of course be valuable, although the (marginal) value of global flexibility is very low. All else equal, it will however be more difficult for flexible DER as they cannot count on a high remuneration of flexibility on the (global) power market.

Figure 7-10: Hourly prices, 1-7 January 2012 (EUR//MWh)



Source: Sweco

The price volatility in Sweden (as well as other markets) is expected to increase in the future. Therefore, the potential value that DER flexibility can capture is strongly increasing at the same time as technological evolutions are reducing the cost of DER flexibility.

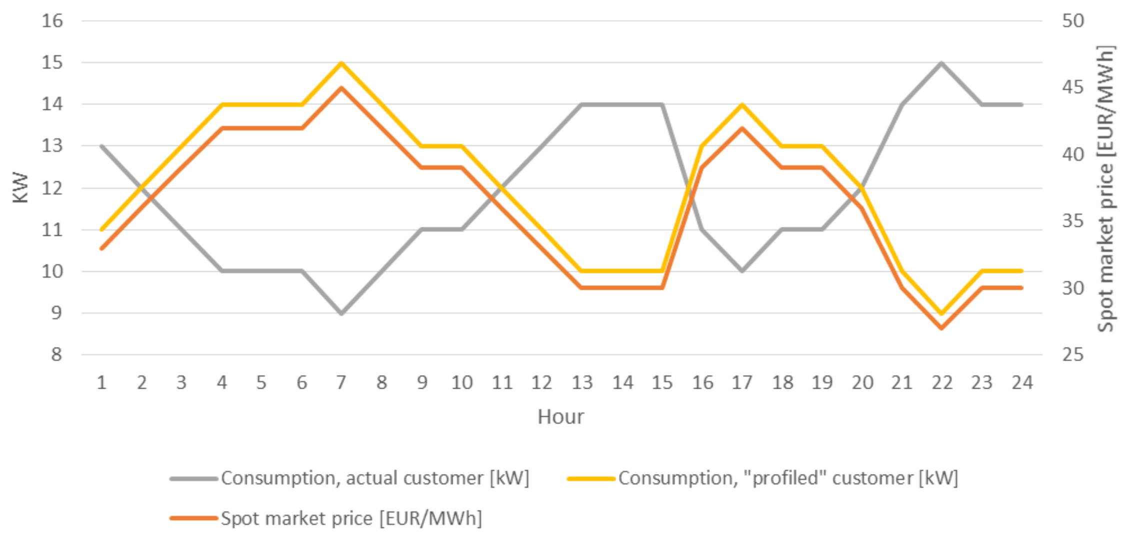
7.2 Lessons learned

7.2.1 How the settlement process affects hourly retail price contracts

Hourly retail price contracts to end consumers is not as widespread as initially projected following the hourly metering reform. A reason to this is the “profile risk” the retailer experiences when the load profile of customers with hourly contracts differ from the “profiled customer”, i.e. the resulting profile when summing the individual loads of all customers in a concessional area together that are settled on a monthly basis by the DSO. An example is made below, where the cost for buying power for the “profiled” customer is greater than for the actual customer due to the actual customer being able to lower their costs by using more electricity when the price is low, while the clear majority of customers used for calculating the “profiled” customer don’t. The differences in this example are heavily amplified to clearly display the risk an electricity retailer has when the DSO decides how the customer is settled.

The fact that the DSO can choose whether to settle an hourly metered customer (with <63 Amps fuse) on an hourly or monthly basis leads to the retailer having to purchase power corresponding to the consumption of a “profiled consumer” (and therefore also paying the market price corresponding to a “profiled customer”) at the same time as charging the end-user with an hourly contract a price connected to their individual hourly use.

Figure 7-11: Example of how the load (and therefore also the cost for the retailer) of a customer can differ based on whether the customer is settle on a monthly or hourly basis.



Source: Sweco

In reality the increased risk lies with the BRP, a role which the retailer often assumes in Sweden, and their problem of balancing a monthly settled template customer which is charged by the hour (because the BRP must always buy power based on the consumption of their profiled customers to avoid imbalance costs).

To combat the risk of having a portfolio whose load profile differ from the profiled customer, a mechanism called profile compensation has been introduced which remunerates or charges the retailer based on the net cost difference between profiled consumption and the hourly spot price (given that the BRP only administers customers with hourly contracts). This effectively removes the incentive for retailers to offer hourly price contracts from a short term economic standpoint.

This creates the consequence of hindering possible business models with DER which incorporates capitalizing on the short term variations in electricity price as the retailers will hesitate against offering hourly price contracts in the DSO applies a settlement method other by the hour.

7.2.2 Hourly metering reform and increased data

The hourly metering reform did not give rise to an increased demand amongst end users to get a new meter because retailers don’t actively market hourly-price contracts.

Only 6,300 electricity customers has chosen an electricity supply contract that requires hourly metering and it requires some work from the customer side to obtain information on hourly price contracts. Another finding is that few electricity suppliers are actively marketing hourly contracts, leading to a low adoption rate of hourly price contracts.

So far, the hourly metering of metering points below 63 amps has not had any significant impact. Part of the reason for that so many meters still have changed since the reform is that network companies themselves have replaced old electricity meters and that the additional cost of an electricity meter capable hourly metering is non-existent or very low. The additional costs now lies with the communications for the collection of metering data. To collect and manage hourly values can now be much more expensive than collecting monthly values. Sweco's assessment is that many electricity distributors reason that "there will be future requirements for hourly metering."

The most obvious way to create economic incentives for the customers are to implement time differentiated and / or power tariffs. Sweco's assessment is that the only reasonable way to work with this development is to implement hourly metering for all customers and work with summing the consumption over a stretch of hours predefined by the time differentiated tariff and then communicating this and possibly maximum power values to the network operator. Such a solution should mean less continuous communication but also means that the DSOs must have sufficient competence to remotely reprogram the meters to avoid costly site visits.

A standardization of an open interface between the meter and the customer is also important for opening up the possibility for new smart solutions/products targeting the Swedish households and thus creating greater customer participation and interest.

Continuous and reliable statistics in well-defined and uniform formats should encourage third parties to develop control products and services as well as contribute to the commercialization of data. Sweco proposes that the current regulatory framework for the electricity network owners' obligation to report metrics to third-party operators is completed with format requirements, as various frameworks is currently in use which requires a lot of work with adaptation from the third party perspective. If the same formats would apply to the disclosure to third-party players it would facilitate the development of third-party functionality (on the basis that the market for third-party players becomes the whole of Sweden) and thereby increase the attractiveness of hourly metering.

7.2.3 Communication infrastructure is essential for DER development

Lack of hourly metering and/or net metering of prosumers leads to customers do not face the real-time value of the electricity, which is essential for aligning the use of DER in a direction more appropriate for the system. And quicker access of consumption data through a data hub will probably give actors such as aggregator’s better preconditions to fulfil their role in a satisfying way.

7.2.4 DSO Tariffs

With access to hourly consumption-measurements for low-voltage customers, new network tariff-models are possible. These can vary in both complexity and cost-reflectiveness. Some tariff-models are beneficial for a certain kind of customers, while others are disadvantageous for the same customers.

The implementation of a new network tariff structure is a significant step and proper information for decision-making is crucial. If the new tariff isn’t cost-reflective it could lead to loss of revenue for network operators as well as increased costs and/or distributional effects for customers. There is also a risk for increased variations in revenue for different tariffs due to climate-conditions. As more network operators gain access to hourly metering data a more detail analysis is possible resulting in a better design of new tariffs.

Changing the tariff can also result in lowered costs for the network operator if the incentives to end user becomes more properly aligned with the actual costs for the grid. One example of this is the DSO in Sala-Heby, an area roughly to the north-west of Stockholm, where a change from the traditional fuse-subscription was made to a pure energy tariff (no fixed fees) for apartment customers and a time-differentiated power tariff that charges the rest of the customers for their maximum power consumption during winter months. Although the incentive for the customer was deemed small, a notable change has been observed with lowered peak demands and a shift of energy from peak hours to off-peak hours. The alleged drivers for the customers were centered on cost savings and environmental motives. What's interesting is that similar tariffs have been implemented in e.g. the distribution grid of Sollentuna as well as Falköping, but where the effects have been much smaller or even failed to materialize at all. The conclusion to draw from this is that, in addition to the tariff design itself, the cost levels of the tariff components, information to consumers and the implementation process itself are all important factors.

In Sweden, different customers have traditionally been categorized and differentiated based on their fuse-size. This has historically been a decent approximation of cost-reflectiveness in the absence of hourly metered consumption-data, but with today's technology this categorization should be replaced by a more cost-reflective differentiation of customers. If it is assumed that the actual costs a customer cause the grid operator is the basis of tariff design the consumption pattern is key. Since analysis show that a categorization based on fuse size divides customers with similar consumption pattern in different groups, as seen by the high correlation between some categories in Table 7-5, new tariff designs are needed.

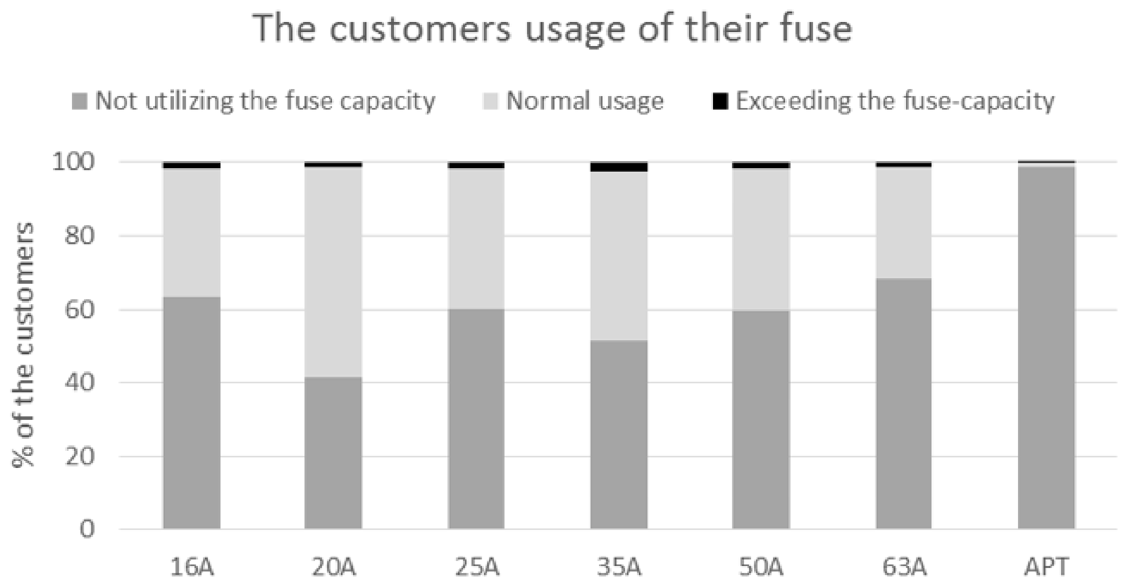
Table 7-5: Correlation between customer groups. 100 % means that they resemble each other perfectly (regarding average consumption per customer per weekday and hour). The absolute energy volumes are disregarded.

	16A	20A	25A	35A	50A	63A	APT
16A	100.0%	99.5%	82.5%	18.3%	31.2%	31.4%	75.4%
20A	-	100.0%	83.5%	20.4%	33.7%	34.0%	76.6%
25A	-	-	100.0%	66.7%	77.2%	76.1%	85.1%
35A	-	-	-	100.0%	97.1%	97.7%	42.2%
50A	-	-	-	-	100.0%	99.0%	58.6%
63A	-	-	-	-	-	100.0%	54.8%
APT	-	-	-	-	-	-	100.0%

Source: Sweco

Fuse-tariffs can generally the perceived as "paying for the option of putting the corresponding strain on the grid, disregarding the temporal aspect". This is not cost-effective partly due to the limited incentives it presents customers with and partly due to the fact that customers don't update their fuse-size as their need is reduced. With the simple analysis of consumption data shown in Figure 7-12 it can be seen that a majority of customers only use up to 50% of their fuse capacity and thus have a larger fuse than needed.

Figure 7-12: Distribution of the customer's utilization-rate of their fuse during a given year, arranged by customer category. The customers are split up in groups; those that exceeds 100% of the theoretical limit of their fuse (Black), those that only uses up to 50% of their theoretical maximum power (Dark Grey) and customers with "Normal usage" which is situated in-between.



Source: Sweco

As a consequence of DER introduction it will be increasingly important for the network operator to tailor their tariffs to the actual circumstances as the diversity of customers will increase. But current rules with regards to network tariffs are also an obstacle in the sense that you cannot implement tariffs purely with the aim of incentivizing customers in certain parts of the grid to help accommodate for a local constraint. The key with the current governing principles for tariff design is the term "customer category". As it is allowed for the tariff to differ in design between customer categories, and the fact that a customer category can be defined in many different ways, presents the ability for network operators to be creative in incentivizing customers in appropriate ways.

Figure 7-13: Summary of the project Tariff synthesis

Tariff synthesis – short summary

A project recently conducted by Sweco took on the challenge of understanding the effects of various tariff designs in a novel fashion and started from real hourly consumption data from almost 200,000 Swedish low-voltage customers during a period of three years (2012-2014). The project have “recalculated” the economic history and by this created new understanding of how alternate tariff-models can affect costs/revenues, partly on an aggregated level and partly for different types of customers. Both assuming ceteris paribus (everything else alike), that the change in the energy-system will accelerate with increasing influx of electric cars and PV-systems, as well as that the technical development facilitates automatic demand response for a larger share of the customers.

Previous discussions have often dealt with swapping from fuse-based subscription tariffs to one new tariff-structure. What has become clear during the project is that the system can benefit more if the approach when implementing new tariffs rather is to offer a range of tariffs. This ensures that all types of customers gets the opportunity to choose the “appropriate” tariff and is therefore presented with the proper incentive to perform cost-saving actions, at the same time as it benefits the grid and the whole collective of customers.

Although the project primarily is conducted from a Swedish perspective, the results and conclusions can largely also be applicable to corresponding regulated markets in other countries. For regimes where there is no unbundling between distribution and retail of electricity, the same logic applies however adding electricity generation to the cost burden. Streamlining tariffs reflecting both grid and retail costs should be possible even easier.

Key findings:

”One model does not fit all” – also goes for tariffs

There are pros and cons with all tariffs. The optimal one would include cost-components reflecting all the costs that the DSO has, but would be very complex for the customers. By offering several different tariffs, it can be ensured that each customer can choose one that they get incentivized by.

Distribution capacity is the primary cost-driver

Tariffs should therefore include power- and time-components to ensure cost-reflectiveness. If simplicity is of great importance (or for customers which only are incentivized by energy-efficiency measures), a fuse-tariff could fill a role.

Categorisation of customers should not only be conducted based on annual power and/or energy-use.

The consumption-pattern is important and should the taken into account when categorizing and differentiating the customer base, so that appropriate tariffs can be set/recommended.

A more complex picture – for those that desire it

A palette of tariffs would indeed present both customers and the DSO with a more complex situation, but there is still a freedom of choice. Customers who don’t wish to change their tariff doesn’t experience any difference, but for those who desire a change there are options available.

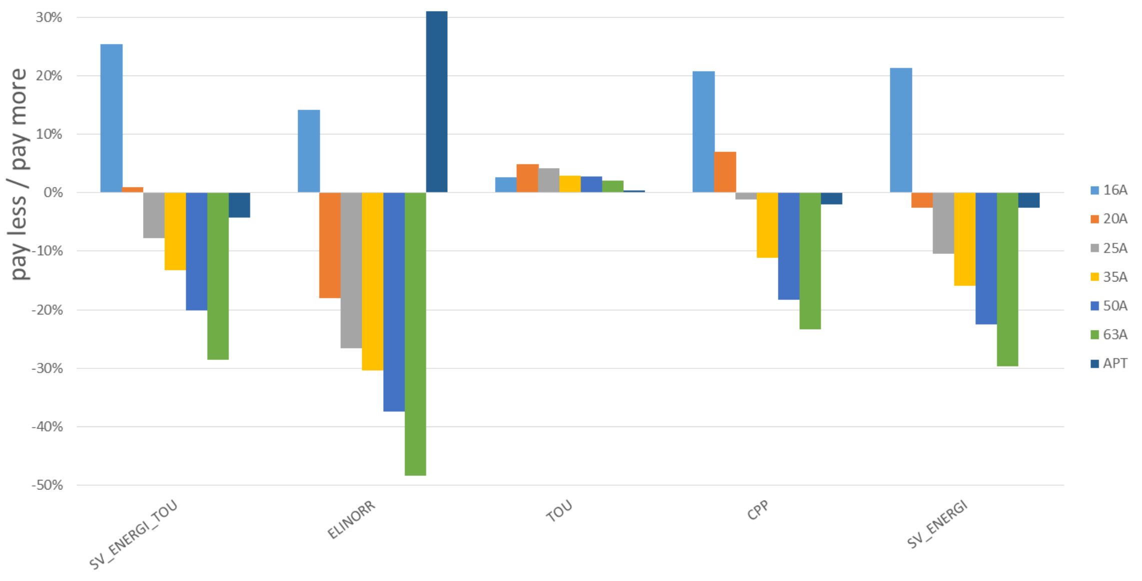
Soruce Sweco

When hourly meter data is analyzed it becomes clear that some customers subsidies the whole collective of customers by having the same costs as the rest of the customers of the same category, even though they use electricity in a way that leads to comparably less strain on the grid as well as costs for the DSO. Certain customer categories are also subsidized by others with the current fuse-subscription, which is made clear by viewing the cost increases experienced by the apartment customers regardless of which tariff structure the comparison is made with. An explanation to this is that DSOs tends to take into account the aggregated load from an entire apartment building (which often results is less allocated costs per customer than if each individual apartment customer were to be assessed individually) when setting rate levels for each customer category.

Other noteworthy trends that can be derived from Figure 7-14 is that the three designs with a power component (SV_ENERGI_TOU, ELINORR and SV_ENERGI) displays a clear trend with lowered unit cost (SEK/kWh) as the customer consumes more electricity, while the time-of-use tariff (TOU) displays marginal change. The reason for this is the flat fixed fee in the power tariffs (as capacity is charge through the power-component of the tariff), while the TOU applies a differentiation of the fixed fee similar to that of the traditional fuse subscription (rising fixed fee with larger fuse) to reflect an increased use of capacity with larger fuse.

As the critical peak pricing tariff (CPP) in essence charges a customer by the kWh/h consumption (and has a flat fixed fee) it resembles a power tariff cost-wise.

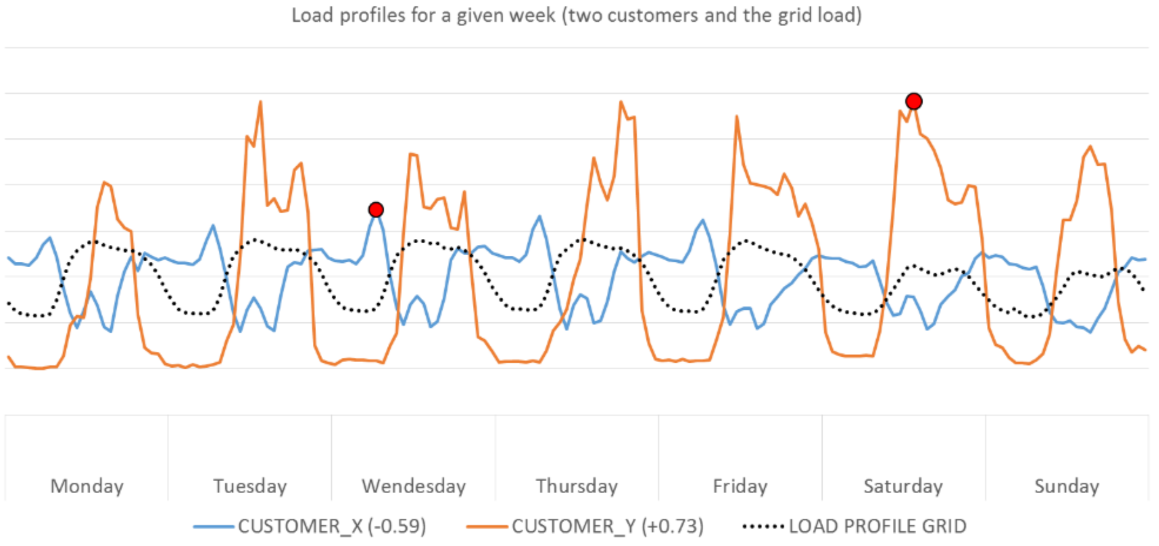
Figure 7-14: The difference in cost for each customer group with the investigated tariffs compared to the costs with a traditional fuse-subscription.



Source: Sweco

The implications using a single tariff design for a group of customers with different load profiles are the loss of customer incentives for an appropriate consumption pattern, and in the worst case the incentives can even work in the wrong directing and causing more costs for the grid. View for instance customer X in the figure below. If that customer has a weekly power tariff where the driving cost is the magnitude of the hourly peak consumption, the incentive for this customer would be to shift load from the night peak to daytime. Customer X can therefore save money by possibly adding to the grid aggregated peak load with a poorly designed tariff. By adding time-differentiation to the power tariff this can be avoided.

Figure 7-15: Consumption during a typical week for the two customers X and Y as well as the aggregated load for the distribution grid. Customer X has a positive correlation with the load profile of the grid (most of the energy-consumption takes place during low-load hours) and that customer Y has a negative correlation with the load profile of the grid (most of the energy-consumption takes place during high-load hours.



Source: Sweco

Network tariffs should also reflect the value of flexibility. In Sweden all network operators are free to set their tariffs as they want. Hence, sometimes the tariffs create incentives for DR and sometimes not. Today´s flat rate energy-based tariffs (i.e. the fuse subscription) have the common trait that they favor solar production, since it remunerates the owner only based on how much electricity is produced and disregarding the temporal aspect. Since solar produces at most in the summertime (when we have a low demand In Sweden) it gives the wrong signals to the market.

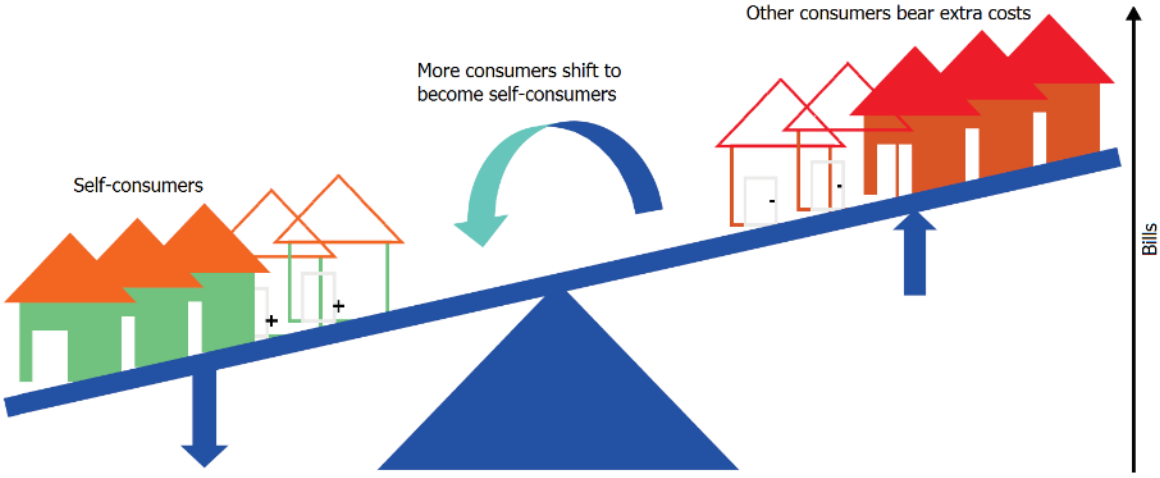
To incentivize the networks operators to bring about a change to more time differentiated tariffs, and in turn incentivizing end users to consume electricity in a more efficient way and, the Energy markets inspectorate developed two mechanisms. After their introduction and to this date two major things can be concluded from this: (1) the industry claims that the incentivizing mechanism are too weak in comparison to other mechanism in the regulation (e.g. security of supply) and (2) many DSO have started the transition process to power and/or time differentiated tariffs. It is thus hard to tell how large impact this single incentive has had.

The fact that pilot studies for alternate tariff designs are not permitted will force network operators to thoroughly think through and analyze a new tariff design before implementing it. This is probably a contributing factor for the relatively slow implementation of new distribution tariffs in Sweden.

7.2.5 Network tariff design (slippery slope)

One of the drivers for behind the meter generation is the retail tariff, but despite an increase in the installation of distributed generation, the grid will still needed. Network tariff redesign becomes essential in the context of the declining cost following distributed resources. Indeed, even though distributed generation reduces the energy withdrawn from the network, the consumer still needs the network most of the time. Unless consumers are prepared to go off-grid, distribution lines and transformers must be maintained. While some of these costs are driven by the amount of energy consumed, a large proportion is either fixed or dependent on the coincident peak demand of consumers.

Figure 7-16: A slippery slope of network tariff design



Source: IEA 2016

Existing methods of cost allocation (e.g. fuse-subscription for DSOs) tend to lead to a bias in favor of consumers that are equipped with distributed energy resources, such as solar PV or batteries. Consequently, the poor design of retail prices creates a problem of sustainability for the power industry as a whole. As consumers are incentivized to reduce their consumption from the grid and replace it with behind-the-meter generation, they avoid paying electricity taxes and contribute less towards the fixed and common costs. Confronted with a shrinking billing base, utilities have to increase their rates, which further increases the cross-over point where self-consumption is cheaper than paying the utility for electricity. This further motivates consumers to install behind-the-meter generation. A slippery slope is created for customers to move to distributed energy, to avoid increasing network costs, and fewer and fewer consumers pay towards the transmission and distribution networks.

Furthermore, by concentrating fixed cost recovery on fewer households who cannot afford the installation of solar PV systems or who do not own their homes, this also creates distributive effects and a redistribution of rents between consumers. This situation is not sustainable. Consequently, network tariffs should be rebalanced away from a volumetric charging basis towards a capacity basis in order to better reflect the cost structure of the network infrastructure. At the same time, a capacity charge reduces the volumetric component of the retail tariff and therefore the savings that can be made with behind the- meter generation. Of course, all consumers will be affected by such charges. They have sometimes been perceived as retroactive changes that affect the return on investment of small rooftop solar PV systems. The right regulatory framework for the efficient development of behind-the-meter generation remains largely an open question. As consumers make their decisions based on retail electricity prices using billing information at the meter, electricity pricing is the key to ensuring efficient decentralized customer decisions. Purely volumetric tariffs combined with simple net-metering tends to lead to a bias in favor of distributed resources. Under such a tariff structure, the cost savings for customers using distributed resources may exceed the savings for the system. In contrast, pure capacity tariffs (where the consumer pays a fixed charge for a set amount of usage) are a simple instrument widely adopted in other areas, for example telecommunications. Consumers easily understand capacity prices, but these prices do not reflect the variable components of the cost and therefore do not promote consumer engagement and can lead to higher consumption. In addition, pure capacity tariffs could excessively reward consumers who install batteries in order to reduce their subscribed capacity. Two-part tariffs that consist of a fixed charge plus volumetric charges offer a better solution. For most distribution systems, the objective should be to define the two-part tariffs or multipart tariffs. There are limits, however, to the degree of complexity that network tariffs can reasonably reach. Increased complexity leads to higher transaction costs, as tariffs become harder to understand, potentially raising acceptance issues for access to a public service infrastructure. It is clear that the design of a network tariff fulfilling the principles of efficient use of the network, full cost coverage, cost allocation and transparency, will require further assessment.

Another reason for lowered revenue for grid owners can be emigration areas, i.e. areas which has declining population. The grid costs is almost the same after some customers leave the grid, but there are less customers left to pay for it. Figure 7-17 shows an example describing how this has happened to one of the DSOs in Sweden, Vattenfall. This is not really a slippery slope, since people's reason for moving away is not really affected by grid costs. It still shows however, actions needed to be taken by the grid DSO.

Figure 7-17: Example of reduced revenue for a grid company, due to reduced population

The North of Sweden to a large extent has decreasing population, especially the parts which are not located at the coast but are more inland. Vattenfall, one of Sweden's largest DSO, has large areas of its network concession located in these areas (see Figure below).

Source: Vattenfall

This has had the effect that their customer base is declining. In order to reach their revenue cap they have therefore increased prices. Vattenfall has increased prices by 15 percent so far during 2016. It is however important to note that the price increase not only is due to less customers, but mainly due to changed incentives in the DSO regulation. The trend has however been for a longer period of time, partly due to decreases in customer base.

Vattenfall applies different prices on different customer areas, one tariff for the North and one for the South. The variable part of the grid tariff is the same in both areas. However, the fixed part varies. As can be seen from the table below, the fixed part of the tariff is 6.8-23.4% more expensive in Vattenfall's northern area than in their southern area.

	Fixed fee South	Fixed fee North	Difference
Apartment	1 244	1 328	6.8%
16 A fuse	2 940	3 464	17.8%
20 A	4 112	4 936	20.0%
25 A	5 140	6 152	19.7%
35 A	7 036	8 640	22.8%
50 A	10 112	12 480	23.4%

Source:Vattenfall

7.2.6 Energy services not primarily targeting the consumption pattern

Even smaller electricity consumers are now able to get hourly metering and consumers with heat pumps are offered control equipment that allows optimization of spot prices and tariffs while maintaining desired heat comfort. The major benefit of these systems is not price optimization but energy efficiency and increased security.

7.2.7 Aggregators

That demand flexibility is well placed to compete with generation of electricity that is expected to be used rarely applies in principle to all forms of capacity markets. The reason is that it typically requires relatively small investments to be able to control the electricity users consumption, allowing the bids can be kept reasonably low. However, if no compensation at all is paid for capacity – such as in the Energy Only market (which is the market regime in Sweden) - it becomes much more difficult to justify the investment, even if it is low. It is much easier to pay an electricity consumer in advance for the right to control his or her facility, compared to promise compensation in case prices will be so high that it actually be necessary to control. This is the background to companies that specialize in working with contracting electricity users and reselling their demand flexibility (so-called Aggregators) can develop in electricity markets with developed markets capacity, but has so far had it harder to establish themselves in Energy Only Markets.

One must remember, however, that a capacity market is not a panacea for developing demand flexibility. It is not easy to design rules for a capacity market that allows for the consumption and production to compete on equal terms and the difficulties in optimizing the demand-response with respect to both market and grid needs not an easy feat just because a new market is introduced. It is also not unlikely that an in-depth analysis will lead to the conclusion that it will be required that a key player assumes overall responsibility for the short-term planning of the system.

7.2.8 Demand flexibility

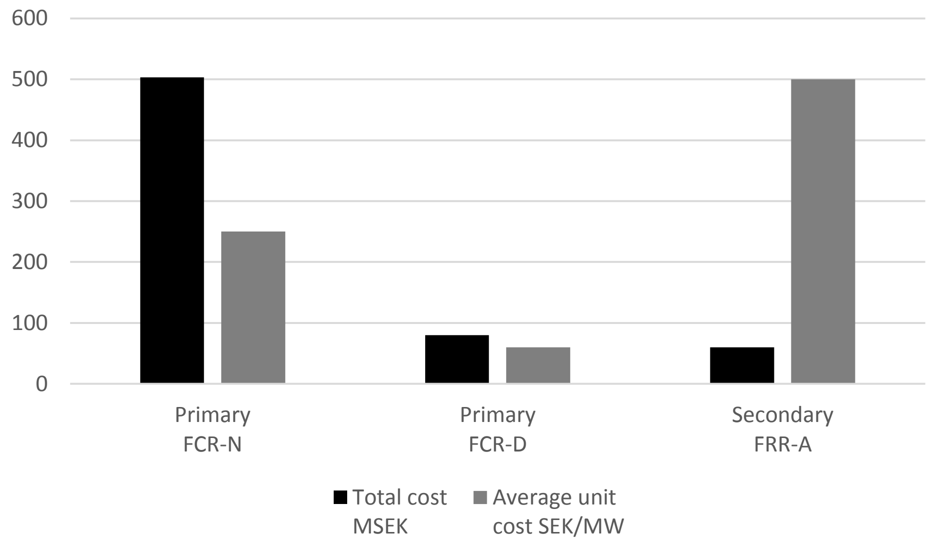
Today we know that there is a great technical potential for demand flexibility. This became painfully visible during a cold winter when the director of Svk told the media that the system would experience a strained situation the following day with high prices as a result, if no further actions were taken. This resonated with the consumers who adjusted their use so much that several retailers (with a financially long position) went bankrupt. This event displays both that the system have a large flexibility if needed as well as that moderate changes can have a major impact on price.

If the expansion of wind- and solar power continues to grow strongly, we know that demand flexibility will compete with the regulation in existing power plants and probably also in some cases investment in new peak-load production and investment in networks. One problem is that the current regulation does not push development forward very quickly because the key players - generators and network owners - often has more to lose from increased demand flexibility than they have to win. Another problem is that the necessary changes in several cases means less freedom for the actors and a more detailed regulation. Measures to ensure that demand flexibility takes part in the price formation in the day ahead market is an example, capacity markets is another.

In the current situation, with a little volatility in electricity prices, it is hardly profitable for home owners to shift load based on the short term price differences of electricity. It is also uncertain if and when prices will be volatile enough for it to be profitable to invest in equipment for automatic load regulation. However, you can save a considerable and predictable amount by optimizing against the time-differentiated tariffs that DSOs offer. The conclusion is that the most effective way to kick-start demand flexibility is to extend the use of time-differentiated tariffs. In most cases a network tariff optimization coincides with electricity price optimization, so that the two reinforce each other. By introducing time-differentiated tariffs the customers are given a predictability that makes it easier to decide to invest in control equipment. Increased demand flexibility will also lead to greater energy efficiency due to more awareness of the energy consumption. Field tests that have been carried out show energy savings of 10-15%.

It is important to recognize that the value of flexibility varies significantly both on a geographical level and across time. In Sweden it has been identified that frequency control is most expensive when it comes to frequency control power (symmetric up- and down frequency control) during the summer at night time, the reason for this being that spot prices are very low and hydro power (the main frequency control in Sweden) therefore prefers to be completely shut off and save water to times of higher prices. Figure 7-18 shows the Swedish TSO's yearly cost for primary (two different types) and secondary frequency control, as well as the average unit cost for primary and secondary frequency control. The cost for tertiary frequency control is not shown in the picture, since this is activated upon request, thus demand is varying.

Figure 7-18: The Swedish TSO's annual costs for primary and secondary frequency control, as well as the average unit cost for primary and secondary frequency control



Source: Sweco

Key features in utilizing DR is the deployment of EVs and charging infrastructure (driven by transport policy incentives) provides part of the enabling infrastructure for activation of EV flexibility. Also the deployment of smart meters (driven by policy decisions) is laying the foundations of the enabling infrastructure for activation of demand flexibility. Finally the deployment of smart home devices, mainly driven by domestic market developments and the internet of things is supporting the activation of demand flexibility, particularly at residential level (e.g. via smart thermostats).

7.2.9 Energy storages

As of today, the DSO is not allowed to purchase electricity beyond that for replacing the losses in the grid, thus making business models based on own ownership of energy storages solely used for utilizing the grid more efficiently more tricky. However, the network operators are still allowed to procure services with the same function although this has yet to be seen in Sweden.

The Energy Markets Inspectorate has recently made a made a statement in the matter which is summarized in text box below.

Figure 7-19: Statement made by the Energy Markets Inspectorate regarding Energy Storages

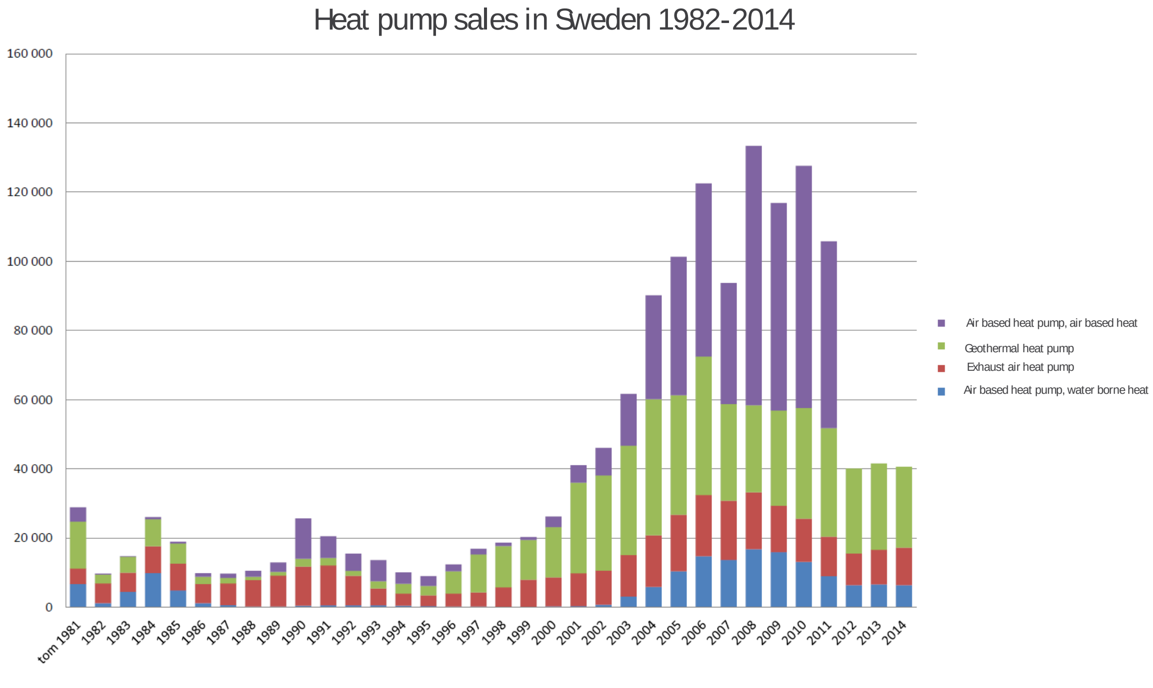
> Energy storage is likely a part of the future solution for adapting the grid, generation and consumption to a larger share of VRES. The Energy Markets Inspectorate equates energy storage to trading or generation of electricity, and DSOs are not allowed to produce or sell electricity for other purposes than to cover their losses or for securing the operation during short outages. The Inspectorate believes that it will be more socio-economically profitable for energy storages to be operated by actors in the competitive market (e.g. generators, retailers or the customers themselves). Furthermore, a mixing of the regulated monopoly operations of the DSOs and the competitive market violates the EU electricity law regarding strict separation of these two types of businesses.
>
> To own an energy storage on a commercial basis is not automatically considered to be in par with trading or generation of electricity. A DSO may own a storage facility and lease its capacity to other actors. However, this operation must be accounted for separately as it is not part of the role of a network operator as stated by the Electricity Act. The Inspectorate will not strive for developing the regulation regarding DSOs and energy storages as this implicates DSOs generating and trading electricity, which is not allowed due to EU law.

Source: Energy Markets Inspectorate

7.2.10 Heat pumps

In recent years, a strong trend for heat pumps has been seen, including both heat pumps and geothermal heat pumps. A slight slowdown in sales of heat pumps has occurred in recent years, while the proportion of single-family homes that are heated by direct electricity or oil is very small. Many pumps sold today replace obsolete heat pumps, rather than other heating systems. Figure 7-20 shows the development of heat pump sales in Sweden.

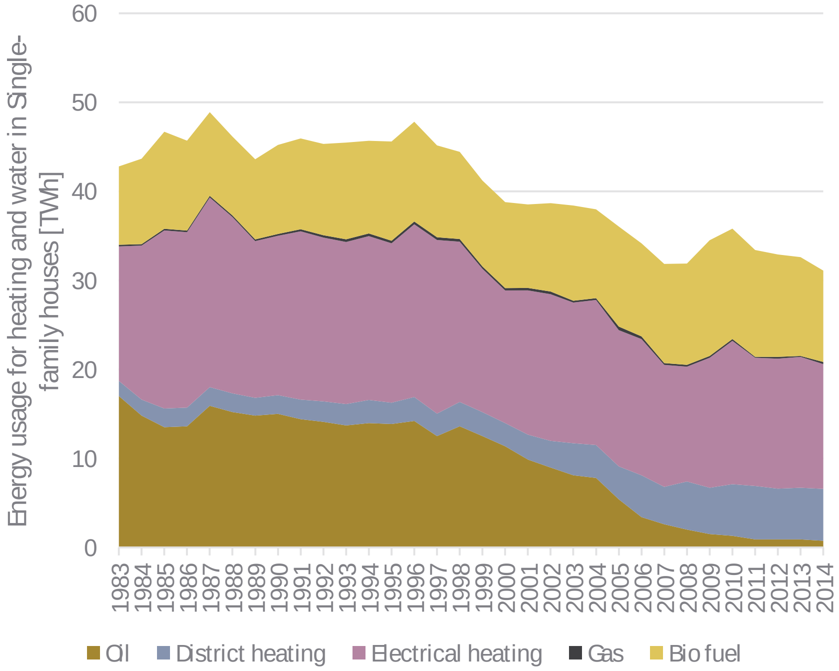
Figure 7-20: Heat pumps sales in Sweden 1982-2014



Source: Swedish Heat Pump Association

The heat pump development have by fact led to demands for more capacity in certain distribution networks, but these requirements already exist today and the additional change to the year of 2037 is considered small. Figure 7-21 shows the development of energy usage for heating and water in single family houses.

Figure 7-21: Energy usage for heating and water in single-family houses

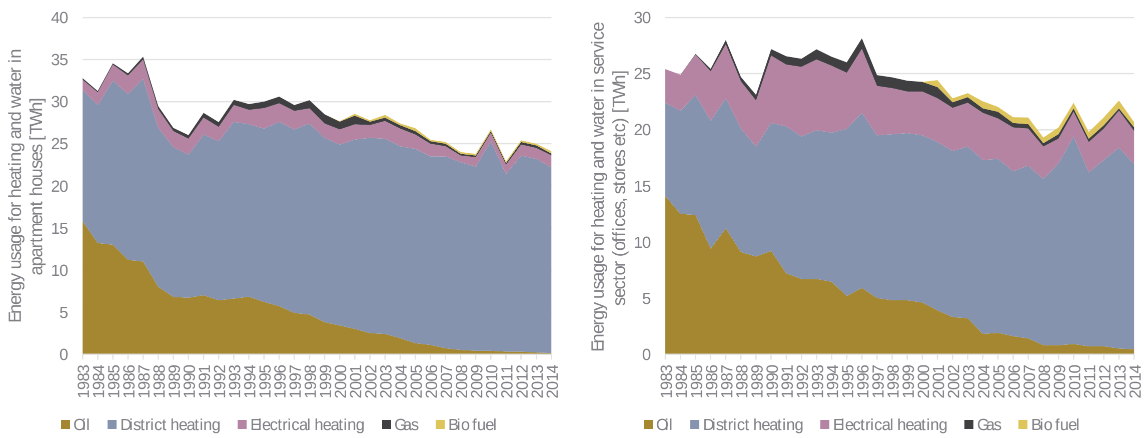


Source: Energy Agency

As can be seen from the figure, oil has declined to almost zero in the sector during the last 15 years, which is largely explained by increased use of heat pumps but also increased use of district heating. Also the use of direct electrical heating has declined. The expansion of heat pumps during later years is not visible as increased electricity usage in the figure, mainly since heat pumps use electricity more efficient than direct heating.

Heat pumps are very common in single family houses, approximately 50 percent of all single family houses has a heat pump as all or part of their heating system. In apartment houses and in the service sector district heating is the dominating heat source, see Figure 7-22.

Figure 7-22: Energy usage for heating and water in apartment houses and in the service sector



Source: Energy Agency

Most cities in Sweden have a district heating system in the center and in some selected suburbs. Heat pumps are mainly installed where district heating is not assessable. This explains why district heating is dominating in apartment houses and service sector, which tends to be located more central than single-family houses. However, a recent trend is that even district heating connected customers are shifting to heat pumps. The driving force behind this Is low electricity prices, heat pumps' technological development of as well as an urge for independence from the district heating company.

7.2.11 Incentives for efficient grid management

The two incentives described in chapter 7.1.1.1 have initially been perceived as too weak to have effect. The network operators argue that other incentives in force, such as the supply reliability regulation, has greater impact. In a report using actual data from a network operator, the economic potential of the two incentives was estimated to potentially amount to a total of 0.2 % of the revenue cap, which validates the network operator's opinion. Although, the report also lays out a scenario with large influx of EVs with control possibilities. In this scenario the projected potential is roughly quadrupled. Another finding in this report was that the economic drivers generated by the incentive regarding lowered losses probably is much less potent than the one aiming for a more even load in the network.

7.2.12 Supply reliability in relation to DER

The Energy Markets Inspectorate had another regulation regarding power supply reliability for their last regulatory period 2012-2015. During this period the economic benefit/loss of increased/decreased grid reliability was split evenly between the consumer and the network operator. The reason for this was to reduce the risk for customers and network companies. Now however, in order to fully create incentives for a socioeconomic optimal supply reliability, the regulatory period 2016-2019 will use the model described above in which the network operators marginal cost for improved supply reliability corresponds to the customers marginal cost for power outages.

The supply reliability in Sweden is today is high (99.98 percent for DSO). There is only a limited amount of customers which have invested in DER due to supply reliability. The energy users which has invested includes hospitals, data centers, larger banks and some larger industries. These have reserve capacity (production or batteries). It is more common to have UPS, which enables controlled shut down of electrical equipment. UPS and reserve capacity sense when the frequency disappears and are activated. It overall works well with these DER in Sweden.

Micro solar production operates in a different way. The regulations for small scale solar power requires that the production is shut-off when the frequency deviates too much from the setpoint. It is also required that the installation is performed by a qualified electrician and that is has permission from the network operator. This overall works well, even if there has been a few incidents when the solar production did not shut off properly (which can be a safety risk). Since micro production such as solar is obligated to be turned off during power outages, increased supply reliability is not a driving force to invest in these type of DER.

Some actors such as hospitals and some industries have DER for supply reliability reasons. However, these remain at a quite steady level. However, DER is growing, and this is not due to supply reliability but other factors described in Chapter 5.

7.2.13 Power retailers offering solar power

As described in 7.1.3 quite a few Swedish power retailers offer solar power solutions to their customers. Research has shown that engagement from local power retailers promoting solar power has had a large influence on the local development of solar power in Sweden. In municipalities where power retailers was early to take initiatives and provide information about solar systems, the expansion on solar DER has been faster than in the rest of Sweden.

7.3 Going forward

7.3.1 Grid challenges following the load-alteration from DER

Requirements to reduce carbon dioxide emissions from energy production, combined with technological changes, is making it likely that we in the future will see a much greater share of distributed and micro generation. The change in production mix also means that we move away from the traditional model where the generation follows the consumption, to a situation with increased demands and opportunities for the demand side to play a more active role. New applications, such as electric cars, will also lead to a change in the utilization of the electrical system. With the current situation we have in Sweden, we have only begun to witness the effects of such a change.

A study on increased DER in a distribution grid in Sweden showed local flexibility gap issues: voltage control (load peaks and voltage fluctuations), reverse power flow. Summarizing the findings of the case study, the increase of PV and EVs leads to new operational conditions that should be handled by DSOs:

- Higher peaks of consumption due to the electric vehicle charging
- Periods of reverse power flow
- Larger power fluctuations which implies higher voltage fluctuations

In future electricity networks with a significant amount of renewable electricity, the challenges are primarily composed of handling a more volatile load curve in the summertime and increased peak load in wintertime. In winter, the Swedish power system has high peak load and a relatively flexible heat load, which in turn allows the system to have some flexibility. In the summer, the system has a negligible heat load, which means that this flexibility is lost. Then, the demand flexibility, particularly from electric cars is expected to be dominant, even if electric cars could help with flexibility also in the wintertime.

Another main issue is the control of active and reactive power in the system. In times of local oversupply, reverse power flows can occur, and electricity is fed to upper grid levels. This oversupply causes problems with keeping voltage and current variations within operational limits. Additionally, power quality can be affected. Fluctuating electricity generation (for instance from large quantities of solar power which can change their output rapidly as the sun is shaded by clouds), can cause local problems with the protection and the fault level of the grid.

Traditionally, fluctuations in distribution grids were caused by changes in local demand. DSOs solved such issues by network expansion measures, e.g. increasing line capacities or installing voltage support devices. Such network development strategies are best suited to deal with demand increase situations, which were the key driver for the development of traditional distribution systems. Such strategies could be less cost-effective or not able to fully solve the problems related to residual demand variability increase. Therefore alternative strategies provided by flexibility actions are needed. In order to understand the nature of these problems, we present these issues in more detail in the section below.

7.3.1.1 Congestion and interconnectors

Trapped power is a major issue which is connected to market based challenges of the electricity sector. Trapped power is socio-economically suboptimal because the "trapped" power in extreme cases can lead to a price collapse. Practically speaking, trapped power means that some parts of the transmission network becomes congested and that all generation will not reach the electricity users (who have WTP). The market impact will result in a non-existent revenue for the producers (they are paid less compared to the scenario without bottlenecks) during the hours of negative rates. With the increasing price volatility the investment risk for investors increase, and the risk for consumers (the timing of price spikes occur and how this coincides with their electricity consumption).

VRES can cause congestions in the distribution networks and impact grid losses. It is possible to experience trapped power (‘zero rates’) due to congestion, something interconnectors or demand flexibility can help avert. On central grid level in a system with a significant share of renewable electricity, production is expected to cause problems with the trapped power. The price volatility is also expected to increase in a system with large shares of VRES, which can be considered a challenge in itself. These challenges are partly linked.

It is estimated that additional spilled energy is to be expect at the larger installed capacities (generation) in the north, and difficulties with surplus production will increase during the summertime due to the hydropower regulation capacity is already strained (which led to spillage during the summer months in simulations).

There is a shortage of capacity in Sweden, leading to notable price differences within the country. In the current system, there is about € 0.6 / MWh price difference between SE3 and SE4 for the coming years, which can be seen as an indication of "acceptable" price difference (after the new connection “the southwest link” is in place).

According to an assessment made by Svk, a maximum of 2 500 MW is going to be built in interconnection capacity between Sweden and Germany, and 2 000 MW between Sweden and Poland. With such strong interconnectors, Svk reasons that voltage stability may be difficult to maintain with such a "skewed" balance between internal and external capacity.

7.3.1.2 Changes in net flow and peak load in different parts of the grid

The biggest impact of the change in net flow will be seen in the suburban distribution network. Following simulations of the NEPP Green Policy Scenario the flows are expected to change and give rise to reversed net flows all the way up to the distribution stations. Many substations in the outer city network will also experience reversed net flows. For the rural network, the net flow is expected to be reversed at a distribution station level only at a few occasions during the summer weeks. For the urban network the flow is not expected to be reversed at all in the distribution station, but occasionally at substation level. At no time will the reverse net flow become peak load and govern the capacity need. That is, the load in the wintertime is still greater than the production in summer.

Figure 7-23: Projected load increases in different parts of the grid.

Higher peak loads in substations

- In the suburban substation, the peak load is increased by up to 15%
- In the rural substation, the peak load is increased by up to 5%
- In the urban substation, the peak load remains roughly the same

Higher peak loads in distribution stations

- In the suburban distribution stations, the peak load is increased by up to 40%
- In the rural distribution stations, the peak load is increased by up to 30%
- In the urban distribution stations, the peak load is increased by up to 20%

Source: Sweco

7.3.1.3 EVs as a capacity driver

Increased transmission in the low and medium voltage networks brings about more losses and higher peak loads as a result of electric vehicle charging also increases losses.

An increase in electric car use and related electric vehicle charging is expected to raise the power demand in the distribution network. The study "*Future demands on the electricity grid*" makes it clear that distribution networks will be facing higher power peaks due to electric vehicle charging and simulations shows that the added load from electric car charging exceeds capacity limits in some places in the modelled network. On distribution grid-level the total load increases for certain points amounts to 30% relative to historical values, and in some instances the grid will be facing reverse flows that exceeds the capacity limit. The industry estimates that today's distribution networks generally have a good residual capacity but although it is considered that aggregated electric vehicle charging leads to the capacity being exceeded locally in some areas. In the same geographical area it is perceived as not unlikely that consumers have a similar purchasing behavior (neighbors interact and influence each other to buy EVs), which further strengthens the argument that the network capacity can get exceeded in certain nodes. According to assessments made in the report *Future demands for electricity grids*, 30% of today's outer metropolitan networks do not cope with the power peaks simulated for 2037. However, a large part of these 30 % will be renewed in the normal rejuvenation programs before 2037. But by using more control-, metering- and monitoring equipment the capacity of the distribution networks can be better utilized and capacity and/or enhancing measures can be postponed.

It is reasonable to expect that EVs will have larger use in more densely populated areas, while complementary technologies (e.g. hydrogen fuel cells or ethanol) will play a larger role in more rural areas. A relatively large share of the EVs are presumed to end up in the suburban grid and thus have the most impact at those places. Electric cars are charged with relatively high power that also risks to coincide for many users with similar diurnal rhythm and behavior. In addition, the risk of this load to coincide with the previous peak load is large (~18-19 o'clock at weekdays).

7.3.1.4 Grid challenges with PVs

For individual households it is natural that PV-generation on some days exceeds the consumption, especially on a sunny summer when electricity demand is low. Surplus energy is fed into the grid and is used by any of the surrounding electricity consumers (e.g. other households). If the majority of electricity users in the region are in the same situation it would result in the net flow changing direction in the substation. If several substations on the same line (cable) is in the same situation, the line can experience a reverse net flow and the argumentation can be applied further up in the grid.

Results from simulations indicate that reverse flows from PVs are unlikely to become a driver of new capacity. But possibly down to the household level if the current connection is very small (e.g. 16 A = 11 kW) and choosing a very large PV-module (> 11 kW). However, this would be handled in conjunction with the connection of the plant.

There exists requirements for inverters in photovoltaic modules to be able to automatically shut the module down in case of grid problems, but when the module is producing a surplus it would be better to be able to turn off parts of production by remote control in a controlled manner. Solar power can cause problems with voltage stability and voltage variations in weak networks. Local production will affect the voltage in the distribution networks. Since the load profile changes with solar power and in addition will fluctuate at a higher rate, for instance when the sun is frequently going in and out of the clouds over the residential area, problems can arise with transients outside specified ranges.

For the most part, these reinforcements can be accommodated within the normal renewal program of the grid. In the long term, one can also imagine that voltage fluctuations are handled with more continuous control via active components, such as automatic tap changers. The alternative to grid reinforcements is to set higher standards for customer's mains. At high outputs the PVs must be switched off or somehow controlled. The standard for connections today requires that the inverter disconnects the output when the frequency or voltage is outside the specified intervals. The treatment involves disconnecting the small production units when the problems become too big, to avoid further risk or damage, not at least for personal security by avoiding reverse voltage. But with smart inverters there is the possibility of PV modules to be a component that actively contributes to the local voltage control by producing or consuming reactive power from the module. This affects the voltage drop in the overhead transformer. In this way, the PV installations can prevent problems, and be a part of remedying problems when they do arise, something that becomes increasingly important as the number of generation facilities increase.

All electricity produced at a different frequency than the frequency of the network need to pass through an inverter. Inverters can be designed to produce or consume reactive power, and thus becomes a component which actively helps to regulate the voltage in the network. With an extensive penetration of PV generation would also be desirable to be able to remotely control the small generation units. This would primarily serve the purpose of being able to execute a controlled shutdown in times of surplus generation, before the limits for voltage or frequency is exceeded. This would benefit grid stability, and such market incentives should also apply to small producers for them not to generate in times of negative electricity prices. With more decentralized production it is important to impose correctly leavened demands on the frequency inverters to ensure proper quality of the signal that is fed out into the grid. The cost for frequency inverters should arguable be placed on the generator and not the network operator.

Local imbalance due to single phase PV modules being connected to the same phase over a large area can cause imbalance and increased losses. To avoid this, either a three-phase PV-module are needed or local coordination to alternate the phase for single phase systems. This problem could require the metering of voltage.

In the regional networks and up (meshed networks) shifted output directions is already a reality (because of operational orientation, production situation, errors, etc.), but in the distribution networks (radial networks), the power direction has traditionally been limited to one direction. Relay protections configured based on the prevailing fault currents should not be affected by the introduction of solar power. An increase in the cost of substations with reverse power protection and circuit breakers on both the primary and secondary side can be imagined in the future. Transformers in distribution stations usually use automated tap changers, and with greater variety of loads, these tap changers are expected to run more frequently with increased wear as a consequence.

7.3.2 Changes in the roles of market participants

The energy flow changes from unidirectional to bidirectional in the distribution grid as end consumers are occasionally producers (when generation exceeds load locally) and generation facilities are connected at lower voltage levels compared to the traditional generation schemes. With this fundamental change, there will be need for new roles and actors in the system (e.g. energy storages, aggregators). The traditional value chains (transactions) might change, and new value chains are expected to emerge with the introduction of new demands, provisions and technologies. Different market players will have different roles in the integration of DERs. As there are several different market designs and technological characteristics in Europe, there is no one-model-fits-all for an efficient and successful integration of DERs.

The changing role for generators is covered in Chapter 8.

7.3.2.1 The Future TSO

Although the Nordic system is relatively easy to operate compared to some central European systems, the phasing out of condensing power plants (especially nuclear power plants in the south of Sweden) and replacement with intermittent solar and wind power leads to increased costs for ongoing maintenance as well as the balancing of generation and consumption. The current system is basically designed to handle variations in consumption, not the fluctuations in consumption plus variations in the generation from PV and wind generation. Svk is aware of this future problem but has historically been regulatory crippled from taking action by gaining better data about the system by e.g. employing metering at lower voltage levels. Today, Svk's knowledge of the real time state of the system only extends to roughly the RSO-level where the grid still is meshed. In lower, radial, grid-levels Svk's knowledge of real time variations is limited. However, the new grid codes from the European network of transmission operators (ENTSO-E) stipulates that the TSO are entitled to the resources they need for managing the system, which for instance includes dictating where real-time metering is implemented. Certain indications suggest that Svk aims to employ demands for metering at more production facilities, even as small as 1 kW, to efficiently be able to handle the increasing amount of DER and VRES.

In a system with a considerable share DER the load in the transmission grid will be reduced, but imbalances might grow. The balancing of the system will get more difficult as non-synchronous VRES constitutes a greater part of the generation as only synchronous generation can contribute with inertia and helping maintain frequency control. For the TSO, greater imbalances means larger risks and a need for bigger and more expensive reserves.

The use of VRES implies a need a higher installed power than needed compared to when the production is fully controllable which is a case more resembling that of today. What happens in future scenarios with optimistic predictions regarding VRES implementation is that the capacity of the intermittent production sources themselves exceeds the minimum aggregated load requirements in the country. A surplus production can of course be exported, but only if there is a demand and capacity in the transmission grid.

7.3.2.2 The Future DSO

The network operators will have to engage in a more active operation of the grid in contrast to the historically more passive approach. In the future operations for the network operator it is consensus that in a first phase it is all about exploiting the residual capacity of the network in a better way. The character of losses in the network is also subject to change. More prosumers resulting in a smaller aggregated need for transfer top-down will result in less losses in transmission networks.

Today, real-time metering and monitoring of distribution networks is typically missing beyond the distribution station's feeders. Although control possibilities exists in some grids in the shape of automatic disconnectors, most grids are planned and operated without more precise information about flows in the grid. More metering generally gives better opportunity to operate the networks closer to the capacity limit and withhold reinforcements until absolutely necessary. These investments would make the operation of the distribution network to more resemble the operation of the transmission network. The investment in a SCADA for distribution would create conditions for Active Network Management.

Increased use of DER would, for the operation of the DSO network, typically imply a decrease in CAPEX (reduced investments in grid) and an increase in OPEX (remuneration of flexibility provision). As the CAPEX remuneration is determined by the regulatory asset base, and reduced investments leading to a reduced asset base, will then decrease the CAPEX remuneration. OPEX remuneration is done in several different ways, but typically an OPEX increase is not allowed to be passed on directly into the regulated revenue. This could lead to incentives not to optimize the CAPEX/OPEX mix. The problems are even more severe if the increase in OPEX comes before a decrease in CAPEX, which would be the case if future investments are avoided or postponed. This is of key importance as the vast majority of the local flexibility needs have historically been resolved by grid reinforcement (CAPEX).

In general, focusing on total costs (TOTEX) rather than CAPEX and OPEX separately should provide better incentives for the DSO to optimize. In practice the regulatory arrangements will be complex, and are not outlined in detail in this study.

The economic regulation of the DSOs is important as it provides the basic economic incentives for the DSOs. The regulation could therefore affect the decisions of DSOs of whether they should invest in more grids and physical infrastructure or solve (some) network problems by using DER and changing the operation of the grid. The first alternative would imply an increased CAPEX, while the second alternative would keep CAPEX lower but likely result in an increased OPEX. Generally speaking the monopoly regulation of the DSOs typically does not provide good incentives for CAPEX-OPEX optimization, and this is in particular the case if the CAPEX-OPEX optimization occurs over time, i.e. not within one regulatory period.

It is uncertain how the costs of the grid evolves, but indications are that the new services that network operators can deliver makes the overall network service more expensive than today. In order to stimulate development, it is also desirable that the network owners have incentives to deliver better than the minimum requirement level. There may also be differences between long-term benefits and the short-term costs, which means that the length of the regulatory period may play a role in the outcome. It is also uncertain if the incentives are strong enough for utility companies to invest in the metering and analysis required to make the grid operation more efficient. This renders reason to develop and adapt the Swedish grid regulation in order to meet future demands.

7.3.2.3 DER-related need for coordination between DSOs and TSOs

With DER, there will be a need for coordination between DSOs and TSOs. DSO grid operation is expected to become more complex and go from the traditionally passive operation to a more active operation similar to the operation of the transmission grid. DSO actions may then interfere with the TSO’s operation. This indicates a need for coordination between the TSO and DSO, potentially with some type of platform for bid exchange and activation of resources. There might also arise conflicts between DSO and TSO. When the conflicts relates to physical requirements, it is important to remember that the conflicts that need to be resolved are subject to the physical constraints. Effectively, physical constraints may in some cases limit the availability of DER for market participation. As local problems can only be solved at the local level, the physical needs of the DSO will take precedence. However, if it is more an economic competition for the same resource the willingness-to-pay will determine who gets access to the resource.

Provision of ancillary services in real time, such as balancing or congestion management, is in many ways simpler. The key issue here is that adjustments have to be made in the settlement process ex-post in order not to financially penalize (or unduly remunerate) third party market participants, e.g.

other Balance Responsible Parties (BRPs). As long as the appropriate adjustments in the settlement are done, there is limited need for coordination between the aggregator and affected BRPs.

7.3.2.4 Supplier or DSO centric model

For the suppliers, price sensitive customers are more challenging to plan and balance purchases of power for, which means that the need and costs for balancing power most likely will increase. The margins in the electricity retail industry are low and the customers demand simple products, which makes it hard to introduce new products and more complex services. And if needed products are brought forward, customers may in turn face an unclear and difficult to understand market with many players. In this sense it’s important that electricity customers only get one point of contact to not complicate their lives too much. This single contact point is currently leaning towards becoming the electricity retailer due to the process towards a supplier centric model, but the DSO could just as well assume this role.

In the supplier centric model, the end user only point of contact is the supplier. The advantage of giving supplier a strong role is that end users that are not satisfied with the service easily can switch supplier. The downside is that supplier doesn’t have and control or responsibility of the physical delivery of power. This model also demands quite some administration to provide suppliers with the information they need to be able to plan their purchases and charge customers spread out over the country.

If this model is chosen the supplier should be given maximum freedom to design the offer to the customer. This means that the supplier pays network tariffs for their customers and are free to choose how these costs are exposed to the end users. If the DSO are to be able to affect the users in their grid they must either try to affect the suppliers via the tariff or sign bilateral agreements with the supplier. A development towards local markets are assuming that the DSOs have clear incentives to demands such a product.

To just continue on this path with minor adjustments does not work if demand flexibility is to become a real alternative to investing in developed networks and / or more production.

While Sweden in on the path for a supplier centric model, the DSOs wishes to reclaim the customer contact. The logic of the DSO centric model is that customer flexibility has the potential to become an important part of the future "smart grid" that is, in efforts to optimize both the operations of and investments in the future local networks. In these networks, there will be local wind turbines, large solar power plants, electrical energy storages, as well as many more consumers of electricity with its own micro- production. If demand flexibility should be part of the solution, network operators must be given a greater role than they have today.

In this model electricity user’s contact only is with the network company they are connected to. The DSO buys electricity for its customers on the spot market and is also the BRP for the end users. Consumers pay the spot price plus an administrative surcharge. The network owner becomes in this model solely responsible for the consumers' whole "physical delivery". The model is administratively simple because most of the information is handled locally. Another advantage is that if network operators are responsible for balancing, their balance can be monitored in real time using just a few data points, providing the instruments for purchasing themselves into balance before the delivery hours when the TSO takes over the balance responsibility. This is also expected eliminate or at least greatly reduce risks for imbalance costs associated with large shares of small scale production and other DER for today’s small BRPs. The retailers are left with the financial trading of electricity and will be the actor customers turn to if they desire some sort of hedged price contract. Price hedging is settled financially and requires no consumption data.

The strongest argument against this model is that a regulated actor gains a great influence over the development. It can justifiably be questioned if it is at all possible to design a regulation that gives network operators an incentive to act socio-economically optimal.

7.3.2.5 Aggregators

The aggregators will most likely play a (very) significant role for the integration of DER and DER flexibility. As the large number, small-scale category of DERs are integrated further into the market (possibly transactions with TSO, DSO, BRPs, Suppliers), the need for an aggregator is probable. The aggregator role could be taken by a number of different actors. It could for instance be the same entity as the supplier/BRP, in principle even the DSO or TSO, however with a significantly different role. It could also be independent aggregators. In order to stimulate competition and innovation it is important that not only established market participants can take on the role as aggregators.

Aggregators already play a key role to facilitate market integration of DER flexibility in aggregated portfolios. This allows creating economies of scale which reduce the costs of marketing DER. Moreover, aggregators are expected to play an increasingly important role in marketing distributed generation, especially as feed-in tariffs start fading away. A competitive regime and a place for independent aggregators in organized markets is needed. The market places and design should resolve solution of conflicts that may arise with other market participants (e.g. actions incurring imbalances on third party market participants, etc.).

The accessibility and policy on access on metering data and information will be a key question on the importance of the aggregator. Furthermore, depending on the size and the actual value chain of a given transaction, an intermediate party is or is not required in the flexibility provision from DERs. An example of two feasible scenarios is the activation of TSO balancing services e.g. frequency control. Either the TSO communicates directly with the providers ("DERs") of frequency control reserves using the appropriate technology, or the TSO communicates with an aggregator that activates the demanded service using the connected DERs. Depending on which of the above scenarios that are realized, different demands and needs are put on IT, regulation and market design. Depending on this, and depending on the demands, different barriers will result in different uptake and optimality. The minimum requirements needed in order for DER to provide a certain service should be provided by both the DSO and the TSO in the relevant market, where uptake and efficient integration should be balanced against the technical requirements.

This role of aggregator can be filled by many different types of entities, e.g. suppliers, retailers, telecommunication companies or specialized new companies. Competition between these entities can stimulate innovation and development of new services and solutions. Clarifying the roles and responsibilities of an aggregator is therefore essential to facilitate active participation of DER in electricity systems.

The actions of an aggregator can have negative impacts on other market participants. For instance, it may give rise to imbalances for Balance Responsible Parties (BRP). There is a need for coordination between aggregators and BRPs when an aggregator is operating on the deregulated market segments such as Day-Ahead and Intraday markets. In particular, if an aggregator is an active market participant on these markets it is necessary that the aggregator has its own balance responsibility, or an agreement with a BRP.

7.3.3 Future DSO tariffs

For the purpose of integrating DER it is important that the network tariffs are designed in a way that provides the proper incentives based on the local conditions. As the local conditions will differ, the DSOs should be allowed flexibility in designing tariffs tailored to the solutions that best meet the local needs, without unduly restrictive regulation. As the tariff is not allowed to discriminate customers based on where they are geographically situated in the grid, this could be challenging to accommodate. One way which has been discussed in 7.2.4 is to instead incentivize customers based on their load profile, regardless of their geographical placement.

The cost-distribution for the grid-service varies with the type of customer and tariff. A power-based tariff favors customers with a relatively low maximum peak load in comparison energy use, while a time-differentiated energy-tariff promotes the use of electricity at times when the aggregated load-level in the grid is lower (in others words when there is more capacity available). Different types of customers are exposed to varying incentives from these two general tariff-types, and it can be debated which one of the two tariff-structures yields the most optimal incentives both short- and long-term which ensures efficiency. Most likely, the optimal tariff-structure differs from grid to grid and between different categories of customers.

It is obvious that different customer types have varying preferences (and potential to alter their consumption-pattern). So instead of ending up in a discussion concerning which tariff is most suitable for which customer, cost-reflectiveness should be the aim. Rather that speaking of “favoring” tariff-structures, the discussion should instead be to which extent a given consumption-pattern and thus aggregated load generates costs for the given DSO. It is on the other hand also important that the tariff is simple and easy to understand for all customers, which possibly could lead to trade-offs regarding the cost-reflectiveness.

To develop a palette of tariffs would definitely give the customers and DSOs a more complex picture, but the freedom of choice remains. Customers who don’t wish to change their tariff, or favors simplicity, doesn’t experience any difference. The customers who wish to be more active and receive the proper incentives and reacts accordingly (thus potentially reducing costs for the grid-service) the appropriate tariff is available. With their knowledge of the electrical grid and power system, the DSO’s have the opportunity to compose correct tariffs and incentives while also informing the customers of their options. In a possible future supplier-centric model the electricity suppliers (or an energy-service actor) could assume the role of advising the customers and offer tailor-made offers combining the grid- and supplier-costs, which makes sure the needs of the grid are satisfied.

Worth mentioning in the context is that this results in increased dialogue between the customer and DSO. The tariff-structure that suits a single customer the best is the one that yields incentives and stimulus for actions leading to increased customer satisfaction at the same time as it increases grid utilization. Increased, customer satisfaction is probably tightly entwined with economic savings. But the customers can also have other drivers. It is key that every single tariff-structured offered to the customers is cost-reflective, since this ascertains funding for the eventual “savings” for each customer. Because for all the savings counting towards the final cost for the customer, the costs for the DSO are reduced equally as much. Some customers have the opportunity to reduce the power consumption while others have prerequisites more suitable for energy-efficiency. These two types of customers ought to be given different tariffs (“incentives”) to make sure that actions are performed. It is therefore suggested that tariff-models are shaped to suit different types of customers and that the customer is presented with the freedom of choice to elect the desired tariff, in resemblance with what some DSOs currently are doing when offering both a time-differentiated and a non-time-differentiated energy-cost for the fuse-based subscription tariff.

If the demands for simplicity is perceived to pose an obstacle for introducing a palette of tariffs, the authors considers the use of a tariff which includes the time- and power-aspects to present the customer with costs based on actual use, as the most cost-reflective alternative while still retaining some simplicity of design. In this case, the fuse-tariff can be kept and function as the tariff customers receive when no choice is made, at the same time as it, in the capacity of being an energy-tariff, presents customers which are only motivated by energy-efficiency with incentives

If DSOs implement time-differentiated tariffs a new market is opened up for energy service companies. Then, there exists no barrier for the actors to also control the energy use based on the spot market price when, and if, it become more volatile. A time-differentiated power tariff is what probably would give the best outcome. A time-differentiated power tariffs are also what delivers the most appropriate signals for the system and can facilitate behavioral changes which are beneficial for both the system and locally. This can be combined with a local critical peak pricing tariff which can be beneficial both for the local conditions as well as for the system.

To increase the incentives for the network operator to change their tariffs the regulation should reward reducing grid losses and costs for the feeding grid subscription. While this is already done today the incentive is too small to have proper effect. And in order to allow for the implementation of a local critical peak price-tariff the requirement for tariffs to be non-discriminatory ought to be relieved.

Today’s time-differentiated tariffs often overcompensate customers in comparison to the grid benefits they cause. In particular, energy -based tariffs, combined with net metering means a hidden subsidy of distributed energy resources. The need of the networks still remains even for customers with their own generation while they pay for a smaller share of the total network costs, which instead is passed on to the remaining customers.

7.3.4 How communications infrastructure interplays with DER

In order to make use of DER to provide flexibility especially on the system level, communication infrastructure is essential. Depending on installed functionalities, smart meters can enable the adoption of dynamic tariffs and the introduction of demand response based on price signals. This requires that Smart Meter data (including prices in high resolution) can be made available to the user. This is not always the case for deployed smart meters but solutions exist to add this functionality. As already commonplace in the US, smart meters could also allow the introduction of automatic demand response programs to mitigate peak events without relying on price signals. In this case grid operators or utilities need direct access to smart devices to adjust their consumption to flexibility needs.

Plenty of (theoretically) controllable demand, storage and generation units are connected to distribution grids. A key precondition for uncapping their flexibility potential is appropriate communication infrastructure, which in many cases is becoming available due to parallel developments (e.g. roll-out of smart meters). Numerous pilot projects are ongoing and their return of experience is expected to further reduce the implementation costs of DER flexibility.

Furthermore, The Energy Markets Inspectorate along with other Nordic regulators within the framework Nordic Energy Regulators (NordREG) found that a Nordic harmonization is promoted if several countries choose the same or very similar models for information exchange.

7.3.4.1 Data hub

A single data hub has a better opportunity to have high IT security than if each individual grid owner has their own system. But the most tangible privacy issue is the sheer amount of metering data, which naturally increases the risks no matter where it is stored. The overall risks that may arise with the implementation of a data hub is manageable by high demands on availability and security, and by an awareness of designing the data hub to be modular so that it isn't locked to a single vendor's technical solution.

A data hub will simplify the access to full customer data for energy service providers. Thus, the data hub can contribute to improving the competitiveness and neutrality in the market, by giving no actors special treatment. At the same time it reduces the dependence of various network operators' local system where the accessibility, interpretation and application of regulations and limited opportunities for change can sometimes be an obstacle. (In the current situation the DSOs stores the original data for the vast majority of the end users, and are thus the authoritative source for all information which are needed to be exchanged between the industry actors for the accomplishment of the electricity market processes.) Through the data hub, a retailer is expected to be able to access historic customer consumption data (of course with the authorization from the customer), which can simplify analysis. It is hoped that this will make transactions easier for both energy providers and customers and therefore increase the supply and quality of available services.

7.3.4.2 Commercialization of big data

With large volumes of data comes the opportunity of conducting so called big data analysis, which can extract aggregated trends combined with analysis of the individual customer's behavior combined with external data such as weather and economics. At the present, big data analysis can be seen used for analysis of new tariff designs and identification of where losses takes place in the grid, to name a few uses.

But what values can be extracted from the large quantities of customer data? This is something we will have a better answer to this autumn, as Sweco has been commissioned to conduct a study regarding categorization of customers based on historical hourly consumption profiles. The project will be granted access to consumption data from several DSOs all across Sweden, incorporating hundreds of thousands of customers in total and the hypothesis is that customers with similar consumption patterns (to some extend) share the same underlying demand, and thus get incentivized by similar tariff designs. The project will also delve deeper into how the retailer can value this information, for instance by gaining increased knowledge of customer behavior and therefore being able to reduce the risk.

One of the long term aim is to design specially adapted tariffs for each customer category which presents the given type of customer with the most effective incentive for achieving an efficient grid management as well as proper price signals from the electricity market.

7.3.5 Demand flexibility – usage and integration into the market

The potential value of DER flexibility is expected to increase as VRES penetration increases. The supply will become more volatile as VRES shares are increasing and conventional power generation is replaced. The more volatile supply will lead to larger price volatility and strengthening the business case for provision of flexibility.

7.3.5.1 Demand response and demand side management

When consumers react to the spot price published on the Nord Pool Spot 13 PM daily and adjust their consumption according to the price signal it is called Demand Response (DR). This may ultimately be automated relatively easily with today's technology.

Another option with demand flexibility called Demand Side Management (DSM) and means that customers demand flexibility is included in the bidding in the day ahead market the day before delivery. This procedure is more complicated because it requires that a balance provider and/or supplier is allowed to control the load for customers and requires a change in the current spot market algorithm. This needed change has been investigated and deemed viable, but has not been implemented due to a stated lack of interest from the market.

7.3.5.2 Implementation of flexibility into the market

Electricity users contributing to the balancing of the power system is basically positive as it reduces the risk of the market power and stabilize electricity prices. It is even necessary that the customers have a certain price sensitivity for the market in general to work, since it is practically impossible to achieve profitability in power plants that are see few hours of use. The problem is that market regulations and institutions are not adapted to effectively utilize this new resource due to factor mentioned in chapter 7.1.7.

It is likely that the major control resources are used for the system's benefit (as done historically, primarily from the generation side) while the small control resources may be used for local network challenges. In most cases the local demand flexibility will also help to balance the system, since the peak load in the local network and the greater system often coincide.

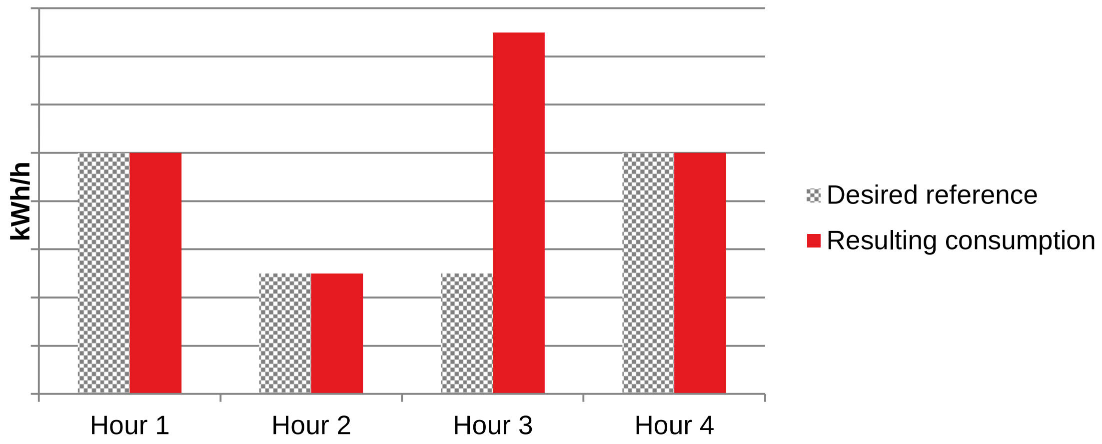
If only a few customers react to electricity prices would not have any particular impact on price formation. Conversely, with a large number of customers responding simultaneously, the effects can instead be negative, creating increased uncertainty and volatility in the electricity market.

As it is not appropriate for large amount of DR to react to the spot price because of the risk of oscillating prices, and neither to the capacity market due to potential differences between the underlying value of demand flexibility and generation (a demand reduction generally lightens the load a bit more in the grid due to that the losses also are reduced freeing up even more capacity, while a generation increase experience losses on its way to the consumer, thus in the end making up for less than the purchased volume), two options remain; the day ahead or intra-day market. An attribute that speaks for the day ahead market is the possibility to place flexible bids, i.e. to sell a specific volume of flexibility for a certain price. The transaction is then conducted at the time where Nord Pool Spot judges it to be the most socio-economically profitable, as long as the asking price and amount are met. But today there does not exist any products that handles demand flexibility based on market price differences, although this product technically can be managed. The stated reason to why this is not in place is because of a lack of demand for it.

Another argument for the day ahead market is that the current model is based on the BRPs anticipating customer behavior when bids into the day ahead market is made, but unfortunately there is no possibility for the BRP to manage this on the occasions when it is the most important is important, that is, when the system is experiencing the most strain and the price is high. As of today, there is no good way to answer this challenge. However, it is in “danger” of ending up in a direction that will require further regulation. Two changes are required; that new bidding rules are introduced in the spot market, and that the BRPs by law or contract be given direct control over how the flexibility of customers' facilities are used. Unfortunately, it is difficult to see how a decentralized solution would look like.

If demand flexibility is purchased in the intraday market because the system is in “up-regulation” it is difficult to take into account for the dynamics of households' buildings affecting the thermal comfort to the next hour. If the system remains in up-regulation an hour afterward the same volume of demand flexibility might not be available, instead some households would probably need to increase their use to compensate for the loss of heating the foregoing hour. Demand flexibility could thus have the potential to cause more harm than good on the intraday market.

Figure 7-24: Potential risk with use of demand flexibility in thermal comfort at the intraday market.



Source: Sweco

7.3.5.3 Demand flexibility business model and remuneration to the provider

The activation of flexibility on the distribution grid level includes two or three stakeholder; the provider, possibly an aggregator (intermediary), and the DSO (end-user). Depending on the number of providers, or the capacity of the average provider, the need for an aggregator is varying. The level of sophistication in the communication and automation level of activation will also play an important part in the usefulness of aggregators. The providers of flexibility are likely to be remunerated by a capacity payment due to the long planning horizon, and the risk for local markets (DSO). The alternative (reinforcing the grid) has a (very) long planning-horizon, and the consequences of failing to meet the requirements (e.g. unserved demand/generation) are to be considered as severe, which further pushes towards capacity remuneration. These capacity remunerations could potentially be combined with an activation fee. Challenges and barriers for a successful implementation are mainly related to firmness of supply, implementation of a suitable communication infrastructure, DSO regulation and the inclusion of the flexibility remuneration in the revenue cap (increased OPEX, see also section 8.4). Also, conflicts might arise between the BRP and the activation of the flexibility, if successfully deployed in a large scale and there is no communication in advance, as this will yield an imbalance from the scheduled portfolio demand. E.g. a BRP could be imbalanced while the grid is under significant load (opposite “directions” demanded), why the signal from these two actors could be conflicting. The “optimal” hierarchy should again be according to laws of physics, e.g. the grid should be superior to market incentives if conflicting.

Another alternative is ToU tariff schemes, which have proven to be useful in long-term peak-shifting. One of the challenges might be reduced predictability when the need for flexibility (“shifting”) is needed in a system with significant generation from VRES, making the “programming” of appliances to consume during “off-peak” harder.

Another issue that should be raised is the incentive and who manages the flexibility. It is considered likely that a supplier with balance responsibility is coordinating the control of the flexible resources at the system level with the current regulations, however, there is a moderate need for transparency due to the operations of the DSO. While the needs for the greater system mostly coincides with the local needs, this is not always the case in a scenario with increased local VRES. The stressed substations (the stations with large shares of micro production and / or electric vehicles) may be feeding the overhead grid, in discrepancy with the general system. When should the incentives be harmonized between local and system level, and when do they go apart? There is a risk that the needs of demand flexibility in the system and the local grid will compete with each other.

In many markets the marginal value of flexibility is low since there are still significant amounts of relatively cheap central flexible resources available. In those markets it will be more difficult for flexible DER to be competitive. The value of flexibility changes for the different operational instances, depending on the instantaneous penetration levels of VRES. High instantaneous VRES levels often relate to a higher instantaneous value of flexibility. Further, the grid is a key enabler for the access to cheap flexibility. In case of grid bottlenecks, the value of flexibility is expected to vary geographically in each node.

7.3.5.4 Flexibility from EVs

In the simulations it is shown that electric cars will help on both systemic and local level, particularly during the summer. It is debatable how much of the electric vehicle fleet that is available for charging, since a significant portion of the car fleet is on holiday and thus "in use" during this time of the year. These can, assumed that they remain within the national borders still help out as flexible resources, however at different terms than when “at home”. One thing that speaks for the use of EVs as energy storages is that the high investment costs for traditional energy storages are lowered.

8 The Future of Centralized Supply

Centralized supply will continue to have vital importance for the foreseeable future. The power sector is however effected by a number of drivers of which the following should be specifically mentioned:

The Paris agreement sets out a global action plan to put the world on track to avoid dangerous climate change by limiting global warming to well below 2°C – and pursue efforts to limit the temperature increase to 1.5°C. The EU and other developed countries will continue to support relevant climate actions. Current mechanisms for Renewable Energy Sources are in effect until 2020 and will likely be extended in one form or another also for the following ten years.

As a consequence the development of VRES (Variable Renewable Energy Sources) will to continue to grow. In Sweden this has primarily been realized through the development of large wind parks leading in part to significantly reduced prices in the Nordic region.

Low prices has made nuclear power unprofitable leading to the shut-down of four units and the future for the remaining units in question. Unique flexibility makes hydro power an important and profitable asset in the Nordic power system.

Together, these topics have created an environment where many of the basic fundamentals of the power system are in question. The Swedish government is currently involved in extensive discussion with the power industry in order propose a parliamentary well supported long term outline for the power sector of the country.

8.1 Current Status

Centralized supply will continue to be the most cost-effective form of generation in the foreseeable future. Yet the primacy of centralized supply in the system could be reduced with the rise of new technologies.

The issue of centralized supply is currently widely debated in Sweden. The reason is that the overall profitability of centralized power generation has dropped considerably over the last years. This has impacted the nuclear power plants to the degree that decisions already have been made to shut down four units of the existing ten. As for hydro power, these units are generally considered to have a significant future potential due to their balancing capacity.

Due to the significant change that the power sector is facing where the current low power prices are one important factor, several assessments have been made regarding the actual reasons for these low prices. Some reasons for the general downward price trend are listed below;

- The economic crisis reduced the industries' energy usage all over Europe
- The introduction of RES prompted predominantly be quite extensive support mechanisms has had a significant impact on current price levels.
- Due to the considerable power connections between the Nordic power market and the Northern European power markets the Nordic price levels are greatly affected by the marginal prices in Northern Europe which largely depend on coal prices which currently are at a historically low level. In addition, the current low prices of emission allowances also has this effect.

8.1.1 Energy storage at level of transmission grid

8.1.1.1 International perspective

The following text describes findings from studies carried out in Sweden but with a more international perspective (not only focusing on Swedish conditions). The requirement for surplus power capacity that comes as a result of a large share of intermittent sources create new opportunities for storage applications compared to the current situation. The foreseen development with regard to energy storage is however somewhat difficult to predict and will largely depend on technological developments and market conditions. One possibility is the development of large-scale storages where hydro pump stations seem to have the most significant potential.

More generally, energy storages have been identified to be of interest in Sweden, not the least at the national grid level, in order to handle the need for reserve capacity, balancing and for momentary grid support. The Swedish TSO (Svk) has investigated the following technologies:

A. Flywheel
B. Power to Gas to Power
C. Compressed air
D. Flow Batteries
E. Lithium-ion

The cost of energy storage is still quite high given Sweden's relatively low energy prices. Storage facilities in operation are based on the use of existing hydro power reservoirs. Balancing power in Sweden – especially primary and secondary frequency control – is priced higher and hence energy storage could potentially be interesting to use in this context. Sweco's calculations (from March 2016) show that batteries and flywheels have the largest potential to be profitable. There are however some obstacles to overcome if energy storage can be used for balancing in Sweden today. These are technical and economical, but mainly regulatory. The National grid would have to change procedures for how they procure balancing power, and it is also not clear if the National grid would be allowed to own and operate energy storage units.

Also, the amount of energy storage units at energy user level is today almost negligible. However, this is predicted to grow, partially driven by an increased amount of electric vehicles (which can be seen as energy storage). This is likely to drive a need for adjusted tariffs.

A number of potential benefits regarding the use of energy storage have been identified including:

- Option instead of network expansion
- Providing load reduction for limited period
- Providing reserve facilities
- Contribution to the elimination of disturbances
- Frequency Regulation

Based on recent studies by Sweco both flywheel and Lithium-ion applications are already promising under certain specific conditions such as for frequency regulation.

8.1.1.2 Results from Domestic Study

From the perspective of centralized supply, the future of centralized electricity generation is heavily impacted, both by the significant development of VRES, most commonly wind power, as well as DER. The development of wind power is further described from a generation point of view below. The impact of wind power has been studied by Elforsk and presented in the report “Förstudie Energilager anslutet till vindkraft” (“Feasibility Study Energy Storages connected to wind power”) presented in the following sections.

Energy storage has features and applications that can enable further expansion of wind power in the local distribution grid. The report looks primarily at energy storage from a grid operator perspective and is meant to be used as an instruction for a possible purchase of an energy storage connected to intermittent production.

The project studies a grid owned and operated by Falbygdens Energi (Feab) by measurements and simulations. The hosting capacity (i.e. the remaining unused grid capacity) is a way to quantify the impact of new consumption or production in a power grid. The hosting capacity indicates the maximum amount of new consumption or production that can be connected without resulting in unacceptable reliability of power quality for other network users. It is possible to increase the hosting capacity by making changes in the network. Examples of such measures are to build new or replace existing lines or transformers, improve voltage control, connection of filters or energy storage. The most preferable method that can be used depends on what power system characteristic that limits the amount of wind power and on the structure of the grid. By studying the hosting capacity of a few different network areas and investigating the associated performance indexes, the amount of wind power that is possible to connect in an exemplified grid is calculated and suggestions are given on how to design and correctly define energy storage capacity.

Examples of studied performance conditions include slow voltage variations, overloading, harmonics, flicker, rapid voltage changes, losses and the number of network incidents.

Five different energy storage applications are described in the feasibility study: increased hosting capacity, reduced costs, peak reduction, reduced losses and prevention of power interruptions. Depending on the application, different storage technologies will be more or less suitable. The report therefore provides an overview of a number of energy storage solutions such as hydrogen storage in a fuel cell, pumped storage, compressed air, flywheels, super capacitors and battery storage.

The project studied mainly lithium-ion battery storage in detail, because a smaller such installation is under evaluation in the same network as was used for the studies. In order to obtain a complete picture of possible options for grid operators, the report also describes alternatives to investments in energy storages. Six different options with the overall objective to increase the amount of renewable energy in the network are discussed: traditional network planning; reactive power control; curtailment of wind generation; demand response; dynamic line rating; and extension of permitted overload or overvoltage.

Three locations for energy storage have been studied in detail:

1 – a distribution substation in a rural grid

2 – in close proximity to a wind farm and

3 – a more remote (less central) point in the network.

For locations 1 and 3, calculations for the design of battery storages have been performed. The results of the study concluded that the main barrier for connecting more distributed generation in relatively strong points in the network was resulting overload conditions. Therefore, the connections points have been studied mainly with regards to overload conditions. For locations 1 and 3 the influence of slow voltage variations have also been studied as well as the possibility of using the energy storages to reduce grid losses. The dimensioning of the battery storage was based on increasing the hosting capacity when overload conditions were setting the limit. For connection 2 no dimensioning of the storage was performed as the storage size would have to be unrealistically large to make a difference. For locations 1 and 3 the battery storage was dimensioned for a case based on the connection of 6 MW (location 1) and 3 MW (location 3) of additional wind generation. A storage installation to cover all the overloads would require unrealistically large batteries that often would be unused. Therefore a storage size was selected at a breaking point where further increase of the battery capacity only would have given smaller increase of captured energy from wind power. This result in the use of storage combined with spilling wind during long periods of high wind. The benefits of installing the battery storage depend on the properties in the local grid. The results in this report suggest however that it is in general better to install the battery in a somewhat remote location of the electricity grid. In conjunction with a wind turbine, battery storage can prevent grid overload. This report has also shown that battery storage could partly compensate for internal conversion losses by reducing the overall losses in the grid. It has also been shown that an increase in the hosting capacity using battery storage can defer other investments in the network.

The regulatory framework for energy storage is not entirely clear, but there are two possibilities for a network operator to use storage to streamline grid operations. The network grid operator can either own the storage or the network operator can buy network services from the storage owner. In the second case, there are several business opportunities for energy storages owners. If the storage is owned neither by a network operator nor by a balance responsible party, the balance responsibility needs to be solved. There is, however, insufficient experience in this area, in order to make a proper judgment of the problems involved in storage. The need for balance responsibility can be an obstacle to cost effective operations. Two business models are used in the report to illustrate the economic aspects of the use of battery storage; the owner is a network operator or the owner is a supplier with balance responsibility. The business model “Balance power” includes the purchase and sale at the Nord Pool Spot market, where the cost of the storage losses are included in the model. The battery is charged and discharged on hourly basis and the storage is cycled once per day. The business model “Grid owners” uses the storage primarily to increase the hosting capacity limit and therefore is cycled in association with the occurrence of overload. The simulations do not include any financial estimates or assumptions on the benefits for the network from the energy storage.

For both business models simulations true historical spot prices from 2011 have been used. The result would most likely be very different if a simulation was performed using another storage application or another business model. When energy storage is still in the research and development phase, it is natural to get high investment costs. In addition, low intra-day variations in spot prices at Nord Pool Spot further contribute to a result where energy storage is currently not a profitable investment. The report indicates, however, that there is a slightly greater opportunity for profitability with the business model Balance power than with the business model Network owners. The estimated investment cost form the basis for a general comparison of battery storage, other energy storage solutions and alternatives to energy storage. Various calculations are presented to show the economic difference between investing in battery storage, hydrogen storage with fuel cell or traditional grid planning. Investing in battery storage or hydrogen storage is a more expensive solution than traditional grid planning. However, one should take into account that energy storage has some advantages that are beyond traditional grid planning, for example, the ability to smooth and balance the wind power's intermittent electricity or serve as backup to the local system. You cannot only look at the investment cost of what each solution entails, but also at the desired functions in the grid. From a network operator's perspective the easiest solution today is probably curtailment agreements with wind power producers. It is rare for maximum wind production to occur in combination with low loads. During the few occasions it does occur in a year, there should be a possibility to cut back production, which provides the lowest cost of investment to resolve these problems. However, the power electronics in the charger for electric vehicles or inverters for motors in the future lead to problems in the network. If resonance problems occur in the network due to dynamic loads, reactive power compensation alone does not solve the problem. It might even exacerbate the problem. Battery storage coupled to a damping controller of the type STATCOM, called E-STATCOM, may then be necessary to stabilize the network.

Upon further expansion of wind power and facing an impending investment in the grid, there are some questions that should be asked. What problem in the network has to be solved? Is it to provide good continuity of supply to the customers? Or store wind power in storage to avoid spilling it? Is it perhaps to deliver electricity of sufficient quality? Or is there some other reason? One question that is not investigated here is who should take the costs of grid improvements needed to integrate wind power. Is it the network operators, wind power owners or the community in general who should pay for necessary future investments?

Given current spot prices the difference between the purchase price and the sales price is too small to achieve profitability with battery storages. A continued expansion of intermittent renewable production will however lead to an increasing demand for frequency control. This demand will largely be covered by hydro based generation. It is however likely that the expansion of new RES as well as reinforced international connections will lead to higher prices for frequency control which in turn will create sufficient conditions for new technologies in the form of energy storage.

8.1.2 Increase of Hydro generation capacity in existing units

Due to the rapid growth of RES in the Nordic power sector, the balancing capacity of hydro generation is increasingly important. The structure of the hydro generation units in Sweden with long river stretches with dams, reservoirs and power plants offer significant opportunities to develop from a capacity perspective. A study, which was assigned to Sweco by Fortum and Skellefteå Kraft, has analyzed the potential of increasing Swedish hydro power capacity. The study is based on existing station heads and station design. Today, the Swedish hydro power units are built from a energy generation perspective, whereas in the future there will be greater focus on power capacity and flexibility. By optimizing future expansion regarding the full stretch of the rivers it is possible to increase both power capacity and flexibility without claiming protected river stretches. The proposed development is designed to increase power capacity and will in most cases not to lead to increase energy output.

The Swedish electricity system is already undergoing major changes in the transition to a renewable electricity systems. In this transition renewable, variable, production technologies will be a prerequisite. The renewable, variable production technologies will most likely consist of primarily solar and wind power. In a renewable power system electric power supply will vary as a result of the increased dependence on weather, while demand must be balanced continuously and instantaneously. Hydropower already plays a vital role for the Swedish electrical system, and is expected to play an even more important role in the future. The total potential for power expansion estimated in this report to 3 400 MW for the 10 largest power-producing rivers in Sweden. If the result is extrapolated to include the power-producing rivers which are not included in the analysis, the potential is 3900 MW. As a comparison, this exceeds the installed capacity of the four nuclear reactors that have been decided to be phased out by 2020.

The absolute and relative potential for power expansion differs between the studied rivers. On average, the installed capacity for all of the analyzed rivers increase by 24% compared with current capacity. The results indicate that hydropower can be developed significantly in order to meet the needs of flexibility, which is a necessity in the transition to a renewable power system. Today major hydro power owners express that there are obstacles for such expansions to take place. One obstacle is existing water rights and environmental permits. In addition, compensation for development rights (market prices), taxes (property taxes) and fees (network charges are also highlighted as barriers to capture the full hydropower potential.

In addition, major hydro power owners also express that the implementation of the EU imposed Water Framework Directive is unclear and could jeopardize hydropower's contribution to power generation and system flexibility which is considered to be so essential for the Swedish electricity system. The study shows a significant potential for expansion, although with a number of assumptions and modeling simplifications.

8.1.3 Nuclear Power

8.1.3.1 Current technology

The nuclear power sector is currently widely debated in Sweden. As a result of low power prices and new security requirement in effect from 2020, the owners of the four oldest nuclear power blocks have decided to discontinue their operations from this date due primarily to poor profitability. The future of the remaining six nuclear power blocks is currently widely debated. The three majority owners of these six units (Vattenfall (Swedish state owned company), Fortum (Finnish Ltd), and E.ON (German Ltd.) are seriously considering to discontinue the operations of the remaining six blocks, also from 2020. The current situation is that the units will be shut down if the special nuclear power tax ("effektskatt") is not suspended.

This issue is of national concern, not only for the reason that such a decision would seriously affect the power supply in the country. It would certainly have a significant impact of the carbon footprint. In contrast to the situation in many other jurisdictions, this issue should not be considered in terms of stranded assets. Since power generation is a competitive business, the business risks are entirely embraced by the power generation companies. In other words this is not an issue from a stranded asset perspective. It should however be mentioned that the Swedish government decided to decommission two nuclear power units for political reasons in the 90-ties. Since this was a forced shut-down, the involved owners were compensated for these losses. It could of course be argued that the government has made decisions, e.g. by introducing support mechanisms for RES has thereby contributed to the current situation with low power prices. These decisions have however been made in order to comply with EU renewable goals and have not really led to any significant opposition from the power companies.

It should also be mentioned that the probable over-dimensioning of Capacity Reserves mentioned above could be considered as a compensation for stranded debt, however only for the generators that can fulfill the Capacity Reserve requirements. In other countries, such as e.g. Spain asset owners were compensated directly when the markets were deregulated.

8.1.3.2 Generation IV reactors

The following description has been copied from SCK•CEN (Belgian Nuclear Research Centre). Fourth generation reactors use fuels more efficiently, which leads to a higher output with far less radioactive waste. Compared to previous generations; the new reactors can generate 50 times more energy with the same amount of uranium. These innovative reactors can even produce energy from existing radioactive waste.

Making uranium reserves last much longer

Nuclear fission of uranium is used to generate energy. In the current water cooled reactors 'slow' neutrons are used in the fission process that only split uranium-235 atoms. Generation IV reactors work with fast neutrons that can convert uranium-238 to fissile plutonium. Because natural uranium contains barely 0.7 % uranium-235 and no less than 99.3 % uranium-238, these 'fast' reactors will use the planet's available uranium reserves much more efficiently. If these reactors are operational by 2030 the current uranium reserves will last for thousands of years. If not, the entire natural uranium reserves will be depleted by 2100.

Less nuclear waste which is less radiotoxic

Because fourth generation reactors use natural uranium more efficiently, they first and foremost create much less radioactive waste. Moreover, these reactors are able to recycle the waste from nuclear reactions via a *transmutation* process. This results in a drastic reduction in radioactive waste, which remains radiotoxic for a much shorter period. With these new reactors the amount of long-lived high level nuclear waste is limited to barely 1 % of the waste generated by current reactors.

Although the future of nuclear power (the future after the economic life span of current nuclear power blocks) is widely debated, there are no immediate plans in Sweden for the future of nuclear power.

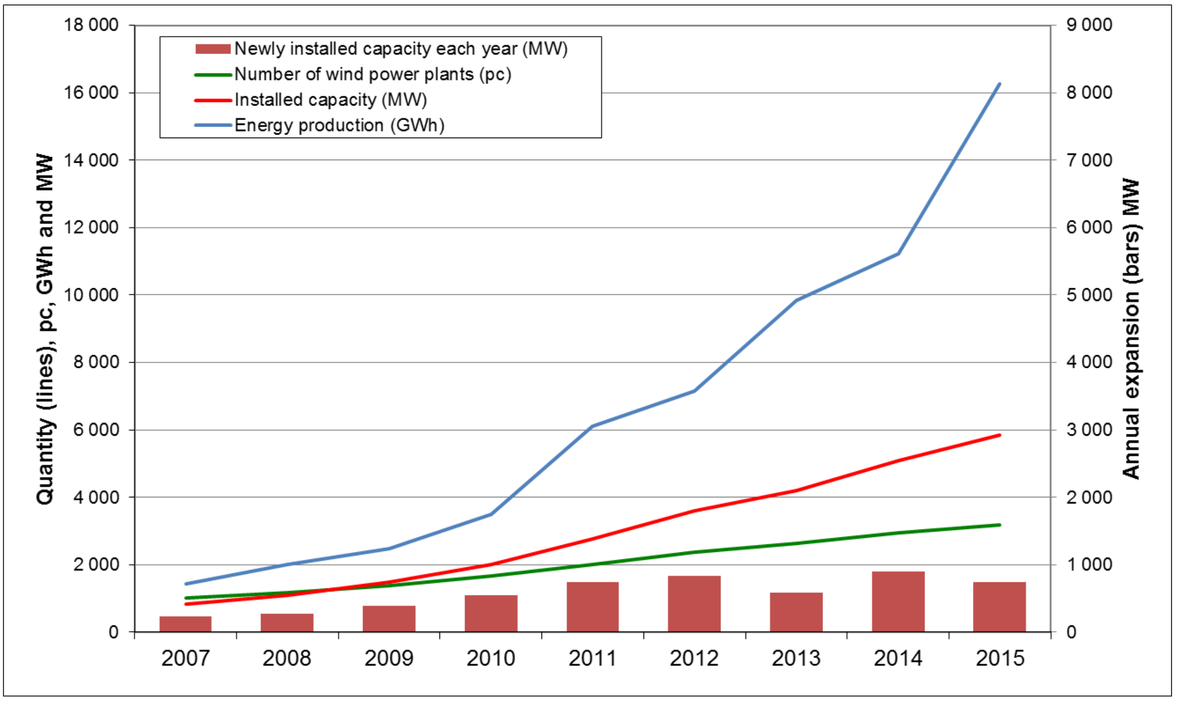
8.1.4 Wind Power

It is obvious that wind power is the single most influential VRES (Variable Renewable energy source) in the Nordic power system. The wind power growth over the past 10 years has exceeded all expectations and has a significant impact on current and future development in the power sector. Figure 8-1.

There are currently no explicit targets for the development of Wind Power in Sweden. The targets for energy and sustainability are general and are not directed towards any specific source of power. The Swedish parliament has however adopted a planning framework to 2020 of approximately 30 TWh of annual wind power production, of which 20 TWh is onshore and another 10 TWh offshore.

There is also a target for the development of renewable energy in the electricity certificate system. Where the goal is to increase electricity production from renewable energy sources by 28.4 TWh from 2012 to 2020. It is still uncertain what will happen to the RES support system after 2020, but it is most likely that the system is prolonged to 2030.

Figure 8-1: Wind power development in Sweden over years.



Source: Swedish Energy Agency analyzed by Sweco

8.1.4.1 Technology cost development example Nordic onshore wind power

The main parameters defining the LCOE for wind power systems are capital costs, wind resources, technical characteristics of the wind turbines and the discount rate. Other costs are variable costs, which include operations and maintenance costs, grid tariffs, taxes, administration, insurance of the turbines and dismantling costs. Of these parameters, the capital cost is the most significant, with the wind turbines themselves accounting for 65-85%, with a narrow range of 70-80% of total installed project cost. Nordic wind resources are good to excellent but differ considerably between countries and regions. In Norway, the whole west coast has excellent wind resources. As investors in Sweden continue to look for large projects, the shift towards projects in the north is expected to continue. This shift results, together with higher hub heights, in stronger average wind speeds for the Swedish projects. On the other hand, the onshore wind resources in Finland are the weakest among the Nordic countries, compared at the same hub height. However, hub heights up to and above 140 m are already being built in Finland making mediocre wind resources exploitable. The generous feed-in tariff system has probably caused some projects being built even where the wind resources are less favorable, leading to higher LCOE. Finland may be the market out of the four Nordic countries that will gain most from the rapid development of low wind turbines, an area of development that has historically been one step ahead of the development of high wind turbines. Denmark has good onshore wind conditions, but the Danish onshore market will most likely mainly see a repowering of older sites. New installations will probably be done at the current hub heights, indicating that the average wind resource for new projects will remain rather constant. The technology that will be utilized in a certain market is dependent on both wind conditions and also the regulations and permit conditions given.

In addition to increased hub height, the trend to increased turbine capacity continues. Historically, both Denmark and Sweden have a long tradition of building smaller turbines, some even as single turbines connected to farms, while Norway and Finland started their wind power build-out later and thus profit from the availability of better technology in the form of turbines with increased capacity. Increasing rotor diameters within all wind classes together with higher hub heights have proven to be a key development for more cost- and energy-efficient wind turbines, both on- and offshore. During the last ten years, there has been a gradual technical development in wind power, improving both energy yield and cost efficiency; this is most notable in the development of higher towers and larger rotors. The reasons for these developments are that a larger rotor makes it possible to capture more wind and to increase the nominal capacity and with a higher tower it is possible to reach better wind conditions, resulting in a higher energy yield per unit. As the turbines get bigger and the average wind speed for new projects are expected to increase in some countries, the generation per turbine increases significantly.

There is a clear downward trend in installed project cost (CAPEX) per MW in all Nordic countries. We see the lowest specific costs in Denmark due to easy site access, low hub height, favorable climate and the fact that the majority of the installations towards 2020 are expected to be repowering. On the other hand, we expect higher specific costs in Sweden and Finland due to higher hub height (120-140 m) and larger rotor diameter as well as higher construction costs including transport to remote locations. In Norway, where climate can be harsh and locations remote as well, we expect hub heights of 80-95 m which drive towards lower specific investment costs for the turbines. In general, onshore wind OPEX costs are expected to decrease in all Nordic countries. Maintenance (service and components) costs are expected to decrease, land-lease costs to remain constant or slightly decrease, dismantling costs to remain constant and grid costs to increase. However, the absolute development of grid costs and insurance costs can be considered as the areas with the highest uncertainty. Service and maintenance is an area where there is still a large potential for development and optimization. Together with the latest generation of wind turbines, there is a trend towards an annual scheduled service interval which will increase the possibility of planning the service to low wind occasions with decreased production losses as a result. The main types of owners in each market will to large extent impact the market for third party service providers. Turbine manufacturers are prepared to offer long-term full service agreements as well as training together with spare part management agreements to utility-type customers who do not have their own service organizations. Capacity factor increases, CAPEX decreases, so LCOE decreases. With CAPEX and OPEX falling, LCOE is falling as well in all Nordic countries. The drivers however, are different: in Norway, excellent wind resources but rather normal hub heights keep CAPEX low and production high, which results in low LCOE. In Sweden, wind resources are good but higher hub heights are required to utilise this wind. Thus CAPEX is slightly higher than in Norway, resulting in a slightly higher LCOE. In Finland, the highest and largest turbines are installed to utilize the low wind. This results in a high CAPEX and together with average wind resources in the highest onshore wind production costs in the Nordic countries. The low Danish investment costs along with low OPEX cost due to easy access and good wind resources result in the lowest cost per energy unit of all Nordic countries.

8.1.4.2 Technology cost development example Nordic offshore wind power

Cost development for offshore wind is driven by development in turbine cost, distance to shore and water depth, which in turn are mainly driving foundation and grid connection costs, but also serviceability and thus OPEX costs. In general, Finnish offshore projects are located much closer to shore and at a lower water depth than most Danish projects. The Danish projects differ considerably between North Sea and Baltic Sea projects. But even within the Danish North Sea projects, there are projects located far off the coast as well projects located near shore. Turbines in harsh North Sea conditions must be designed for both higher wind speeds and turbulence, but also for a more corrosive environment, adding to turbine costs. In addition, Danish North Sea locations are on average located further away from shore than Danish Baltic Sea projects increasing grid connection cost, while higher water depth requires slightly higher foundation costs. Capacity factors are already high for the latest Danish projects (Horns Rev 2, Anholt) and are generally higher in the Danish North Sea. Finnish Baltic Sea locations on the other hand have the advantage of low water depth and proximity to the shore. Together with less turbulent winds and the lower salt content in the Baltic Sea, conditions, our capacity factor assumptions are mainly depending on the relation between generator size and rotor diameter. Therefore, forecasts may change significantly with different turbines configurations used and should be used with care for strategic assessments.

Anecdotal evidence from e.g. the Danish offshore bidding rounds shows, that there is a downward trend in cost per MW installed. Although good historic data on CAPEX and OPEX for single countries is rare, comparing a number of projects for comparable locations such as the North Sea allows the conclusion, that there is a downward trend in cost per MW installed. We generally expect Danish Baltic Sea projects at lower costs than the Danish North Sea projects. We expect Finnish offshore OPEX to decrease, driven by good accessibility of the sites. Swedish offshore wind power projects are comparable to Danish Baltic Sea projects with hindsight to wind speed, water depth and corrosiveness of the environment.

8.1.5 Combined Heat and Power Generation

A significant portion of the power supply is generated in CHP units, predominantly in relatively densely populated areas in Sweden. CHP plants have the advantage that electric power and heat are jointly produced and with a very high overall efficiency. Operating expenses are in general terms relatively low. The disadvantage however is the district heating required an extensive and quite expensive infrastructure in heat water piping and building sub-stations (heat exchangers). The resulting capital requirements are in other words quite high.

District heating is an unregulated business in Sweden. The district heating rates are set on competitive terms. This is often debated since district heating is a natural monopoly. From an economic perspective there is no sense to have competing district heating units or parallel piping. It can therefore be argued that the sector should be subject to regulation. This is however not the case since there always are alternative heating methods. In the 70-ties a principal source of heating were local oil-fired furnaces. This was pushed out by inexpensive electric power in the 80-ties and the development of competitively priced heat pumps from around 1990. Although these alternatives provided reasonable competition the business condition for district heating were quite favorable and prices increased over time. It should be pointed out that district heating has a quite considerable lock-in effect. Once all the investments have been made it is quite difficult from an economic perspective to discontinue supply. So, the main competition has been in the phase of connecting a new building.

This quite comfortable situation has however gone through a quite dramatic change as a result of the low power prices. The prices not only create an environment where heat pumps are more attractive than district heating when connecting new buildings. Also older buildings are being disconnected and shifting to heat pumps as an alternative to district heating. This has in some cases led to a so called death spiral since it is more expensive to run the business for each consumer that opts out. It can therefore be said that district heating today in many cases is truly competitive. It is quite common that customers install a heat pump to supply for the main part of their heat demand, but keep their connection to the district heating grid as backup connection. Hence, they pay only a low cost to the district heating company since they can cover most of their heat use using their heat pump. This is very cost driving for the district heating company since the peak load is always most expensive to produce. This has led to district heating companies introducing peak load tariffs, which are tariffs with a very high price during peak-load hours for customers with a low total heat outtake during the year. This has the advantage of allowing the district heating companies to cover their costs whilst at the same time not driving away existing full-time-district heating customers. If a peak-load customer decides to terminate their district heating connection, this is a much smaller loss for the district heating company.

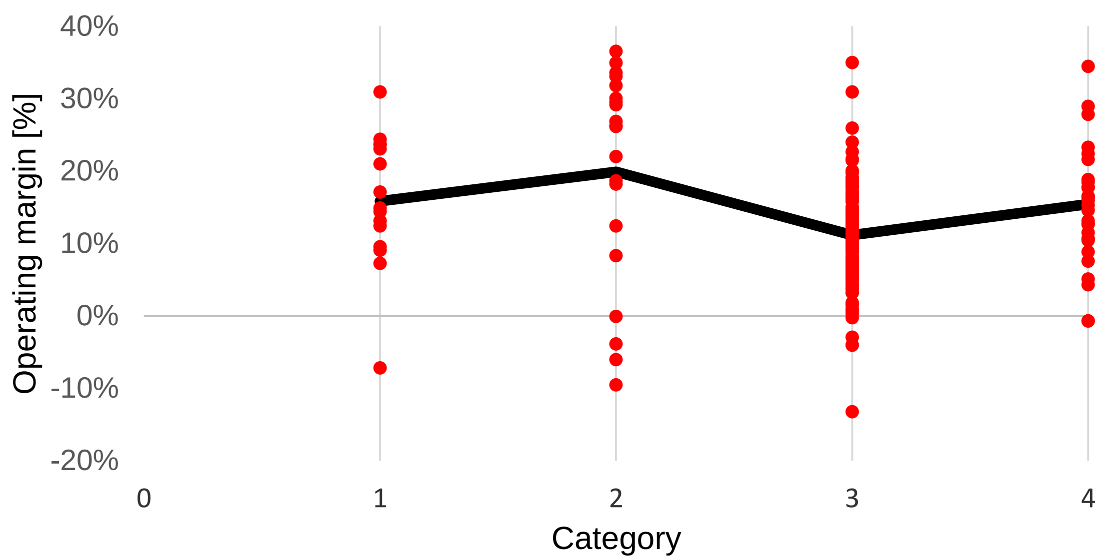
8.1.5.1 Ownership district heating

To large extent, district heating in Sweden has been built up by municipalities or municipality owned companies. During the last decades a change in the ownership structure has taken place. Initially companies such as Vattenfall, E.ON and Fortum gained market shares through acquisitions. In addition there are some companies focusing on operation of smaller scale district heating operations, e.g. Neova.

The district heating industry in Sweden can be divided into four categories. The first category consists of large energy companies, i.e. “traditional” energy companies (utilities) which are spread across the country. These companies are generally expected to behave in a relative commercial manner, although there are differences between the companies. Included in this category are Vattenfall, Fortum, E.ON and Statkraft. The second category has been labelled financial investors. This covers a relative broad scope of companies, ranging from companies owned by large international investment funds to family owned companies. The third category is municipality owned companies. The companies within this category are very different both in terms of size and commercial orientations. As municipality owned companies political objectives may be important at least for some of the companies. The effectiveness of the corporate governance also differs substantially between the companies. The fourth category, “others”, includes small and medium-size energy companies owned by private owners, cities, economic associations as well as foundations.

Figure 8-2 shows the operating margin per company (net sales/operating profit), sorted into the four different categories. The figure is based on the companies reported numbers to the Energy Market Inspectorate for year 2012. This figure also gives an indication of the number of district heating companies in each category. Please note that the trend of financial investors procuring district heating grids has continued since 2012.

Figure 8-2: Operating margin for Swedish district heating companies



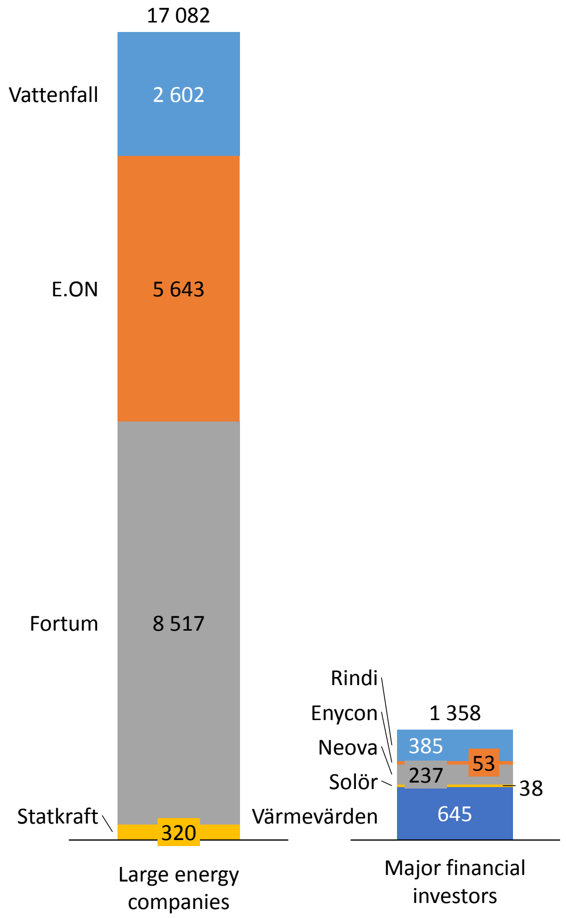
Category 1 = Vattenfall, E.ON, Fortum and Statkraft; Category 2 = Financial investors; Category 3 = Municipality owned; Category 4 = Others; Black line shows the average operating margin per category. Each production company is monitored separately (by the Energy market inspectorate).

Source: Swedish Energy Markets Inspectorate, 2013

As can be seen from the figure category 2, financial investors, have the highest average operating marginal (20%). The large energy companies have an average of around 16%, and the municipalities have the lowest operating marginal, around 11%. The “other”-category shows an average operating marginal of around 15%.

Figure 8-2 shows the number of companies within each category, but does not show the differences in sold heat volumes. The total sold heat in 2012 for the major energy companies and major financial investors is shown in Figure 8-3. As can be seen from the figure, the four largest energy companies in Sweden make up the majority of the market volume. Please note that the numbers are a bit old, even though the overall picture remains. The municipal companies and "other category" overall have smaller sales volumes, even though there is a quite large amount of them and they therefore in total make up a large part of the market.

Figure 8-3: Total sold heat in GWh in 2012 for the large energy companies and major financial investors



Source: Swedish Energy, Swedish Energy Markets Inspectorate, 2013

8.1.6 Capacity Reserves

Although, the overall Power generation capacity in Sweden is considered to be sufficient for normal conditions, the price signals from the spot market have not been sufficient to secure necessary development of reserve capacity. The demand for Reserve Capacity has also been emphasized by the significant development of RES, primarily wind power driven largely by the Green Certificate mechanism.

For this reason, the Swedish TSO has somewhat reluctantly been engaged in the procurement of Capacity Reserves. Over this period, there has been an ambition to resolve the issue of capacity reserves with a market based approach. This ambition has however not materialized to date.

The overall costs associated with the Power Reserve are paid to Svk by the balance providers.

Svk explains their capacity reserve function as follows:

"To meet consumption peaks during cold winters we procure capacity reserves. A stakeholder in the electricity market can participate either through an agreement of reserve generation capacity or through an agreement of load reduction. During very cold winter days there may occasionally occur situations where there is a risk for power consumption exceeding power production. Under such occurrences of power deficits Svk will call off previously negotiated reserve capacity contracts. These strategic reserve agreements are part of the power reserve. They have been created by Svk and include agreements with electricity producers to generate additional capacity available and with the electricity consumers and electricity suppliers to reduce electricity consumption. The power reserve will be available between 16th November and 15th March.

Current legislation stipulates that Svk (Swedish TSO) should arrange for a Capacity Reserve up to 2000 MW during the winter period. The law is in effect until March 16, 2020.

The by-law regulation stipulates the exact level to be procured by Svk for each winter season.

The value 2000 MW has been decided by Svk. There is no exact calculation behind this value but rather a brief assessment based on which power plants Svk wanted to prevent from shutdown. Sweden – as the rest of the Nordics – do not have a specific quality target such as the one in for example UK. In the UK there is a quality target that power outages should occur maximum three times during each ten year period (Loss Of Load Expectation). If Sweden had a quality target such as this it would have enabled more specific calculations of the size of the capacity reserve, now the number is more a rough estimate.

Historically only a few hundred MW in the capacity reserve have even been activated simultaneously. FCR-D however, the Frequency Containment Reserves, which is described in Chapter 7.1.7, is based on the size of the nuclear reactors. The dimensioning of FCR-D is based on the ability to handle a sudden production drop in Sweden's largest nuclear reactor.

The fact that the full capacity reserve has never been used indicates that it is over dimensioned. It could however be argued that the dimensioning is appropriate, given that the Nordic system has large variations in load (large weather dependent load) and generation (different amount of hydro available different years). The dimensioning depends on the preferred margins.

Sweco's assessment is that it would be a good idea to procure a mutual capacity reserve for the Nordic electricity system, even though this is not the case at the moment. The Swedish capacity reserve is only procured in Sweden. Finland however has a capacity reserve with overall the same rules as Sweden, which enables the two capacity reserves to complement each other. For example in a situation when the Finish reserve is activated this might be enough for the system, so that the Swedish capacity reserve do not require activation. Svk is procuring FCR-N (Frequency Containment Reserves, see Chapter 7.1.7) for Denmark.

8.2 Lessons learned

8.2.1 RES supporting mechanisms

As a lessons learned, the energy only market combined with electricity certificate system can be said to have created incentives for additional VRES (*Variable Renewable Energy Sources),* including intermittent wind- and solar power, rather than generation with higher availability. The issue of capacity has thus become an increasingly important topic.

Another important factor is how fast new technology can come into play when the conditions are favorable. A good example is the development of wind power in the Nordic region. For a long period only moderate development was accomplished. However, when the technology had reached a certain point of sophistication and reliability and when the economics became favorable which especially was the case when the electricity certificate system came into play, then the preconditions were right and a number of both existing and new stakeholders were attracted. It should also be said that the way the electricity certificate system was designed in a way that actually provided an advantage to early adopters since the system was originally set up for a certain period of time. This actually meant that the sooner the turbine was in operation the longer it would actually generate certificates.

8.2.2 Capacity Reserve Extension

The government has recently presented new proposals to extend the law of power reserve. The power reserve is in use at occasions when electricity use in Sweden is greater than the supply of electricity.

The decision in 2010 to phase out the power reserve was taken under the assumption that the prevailing conditions at the date of expiry (2020) would give customers greater flexibility in their use of electricity and the market would drive up flexible production resources. This has not happened. Therefore, the government proposes to extend the power reserve for a further five years. The power reserve is a form of guarantee for a safe and stable power grid when electricity use is high. It was emphasized that this is not a solution to ensure the long-term electricity supply for the country. There has been criticism that the power reserve previously consisted of oil-fired plants. Therefore, the Government now proposes that environmental requirements should be set in the contract. First and foremost, it is important that we have a power reserve that meets the technical requirements needed for a reserve in the electricity system. It has also been determined to cover the required needs for reserve capacity by using renewable energy sources to the highest degree possible.

The Council on Legislation therefore proposes that the validity of the Act on the power reserve should be extended until 15 March 2025.

8.3 Going Forward

8.3.1 Business Models for large utilities

As described above, the large utilities having both electricity generation, distribution and retail (electricity supply) now see a need to rethink their business strategy and decouple their business in order to reach “The New energy consumer”. Hence, we see effects such as E.ON dividing their company into two different businesses. One part of the company will target “The New energy consumer”, and will be more focused on consumer relationships and enabling a green transition and prosumers. The other traditional part, Uniper, will instead have focus on traditional large scale electricity generation. Other examples can be found in some companies that have started to profile mainly their more customer oriented part of their operations. More companies are likely to follow.

Some experts claim that large scale generation has no future, and that companies such as Uniper will only cash in what they can during their remaining years in operation before DER takes over completely. Other believe that large scale generation will continue to be the most cost-effective and that increased market integration, need for balancing power and backup capacity will shift the market to its advantage. Hence, the power business will change in a number of ways. The following aspects are discussed in the following sections:

- Capacity mechanisms
- Power export
- Balancing electricity market
- RES support system after 2020
- TSC challenges

8.3.2 Capacity mechanism

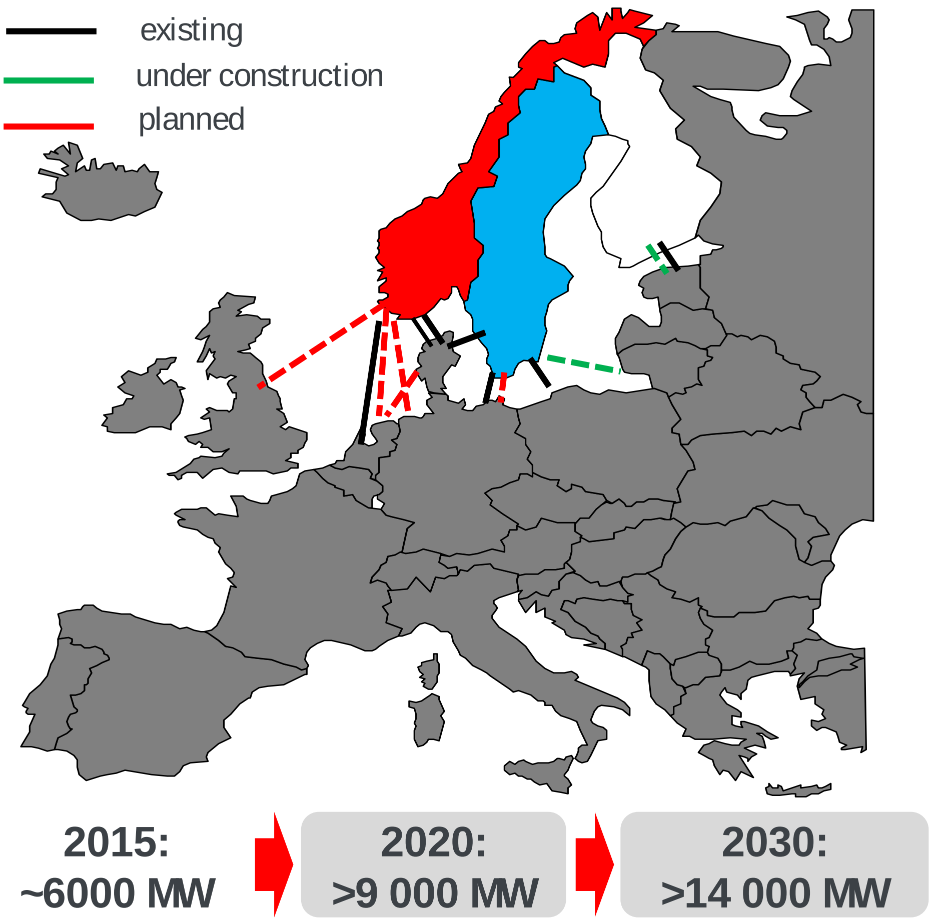
As described in Chapter 4, Sweden has an energy only-market, meaning that electricity generators only gets paid for when they generate electricity. The exception from this is the small capacity reserve during winter (described previous in this chapter). The current low spot prices, the increased amounts of intermittent energy production and the announcement that some nuclear reactors in Sweden are decommissioning before 2020 has however increased the discussion regarding capacity markets in Sweden, which is one solution to finance flexible central capacity is capacity payments. Many countries in Europe, including Germany, UK and Spain has already introduced capacity markets of some form. The majority of large utilities in Sweden – included the governmentally owned Vattenfall – are now actively pro capacity mechanism (after previously been against it). The large generators look upon it as a way to increase payments in times such as these when the spot price is too low to incentive new investments and even decommissioning is considered for some generation facilities. The energy users see it as a way to increase security of supply when intermittent generation is a large share and when generation with higher availability (otherwise) is decommissioning. For example, the general business organization in Sweden (Svenskt Näringsliv) is at the moment carrying out a study regarding market design in which capacity mechanisms are examined.

However, depending on their regulation, capacity payments could add distortions to the market. If the capacity payments lead to overcapacity, market price volatility is reduced. Therefore, the incentives for storage and demand flexibility are being reduced. Making future markets provide sufficient incentives for peaking capacity and flexibility is a key challenge towards systems with higher VRES shares.

8.3.3 Power export

Sweden currently has surplus power generation. The situation is likely to stay like this up to 2020 and some years after that. After that, some generation facilities will decommission and Sweden is likely to go towards electricity generation deficit (given business as usual). Sweden is in a situation of very low spot prices. The European continent, such as Germany, Denmark and Lithuania, have considerably higher average spot prices. The ongoing market integration enables Sweden to export its excess power generation to a higher spot price, see Figure 8-4. Hence, the power industry in Sweden is very pro increased market integration and sees it as a business opportunity. The physical integration can also be looked upon as increased security of supply, especially later on when there is less over capacity in Sweden (towards 2030).

Figure 8-4: Overview of Nordic market integration. Please note that there are also several interconnectors between Norway, Sweden and Finland



Source: Sweco

8.3.4 Balancing electricity market

Swedish hydro power (as well as Norwegian) has very good capabilities to regulate intermittent power production. Regulating power usually pays better than spot prices. Hence, large hydro producers sees it as a business opportunity to sell regulating power, preferably also to other countries with large share of renewables such as Denmark and Germany.

8.3.5 RES support system after 2020

It is still uncertain what will happen to the RES support system after 2020, but it is most likely that the system is prolonged to 2030. The possible outcomes are 1) prolong (maybe slightly adjusted) the electricity certificate system. 2) Invent a new support system such as an auctioning system. This is not discussed in Sweden but is a possible alternative 3) No support system after 2020. The electricity industry is arguing for this since the system actually reduces electricity prices. However, this alternative has low political support.

8.3.6 TSO challenges

The Swedish TSO has long ago realized that the current energy sector structure will go through dramatic change. The increased supply from VRES will create significant planning and balancing challenges. Just as it has been necessary to plan for changing load conditions it will become increasingly important to plan for supply also. For this reason, there are currently proposals to collect real-time generation data from all productions sources larger than 1000 kW. With access to this information the objective is to improve supply planning over time.

8.3.7 Power supply

Due to the significant challenges that are described above and primarily the future of the nuclear power sector, the Swedish government has initiated an energy commission that is currently involved with the extensive task of proposing an outline for the future of the Swedish power sector and gaining parliamentary support for this proposal. The goal is to present the plan by the end of 2016.

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