TAMPERE UNIVERSITY OF TECHNOLOGY

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DISTRIBUTION SYSTEM OPERATOR AS AN ENABLER OF THE ELECTRICITY MARKET – CONNECTING SMALL-SCALE PRODUCTION AND DEMAND RESPONSE

Master of Science Thesis

Examiner: Professor Pertti Järventausta
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ABSTRACT

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The electric industry is in a turning point. The electricity market is being developed to be more harmonised in the Nordic countries and the market model will be more supplier centric to make it easier to understand for the customers. Then distribution system operator's (DSO) role will be more limited and more concentrated on merely transportation of electricity. Nevertheless, as the metering will stay DSO's responsibility the other market participants are dependant on DSO's reliable operation. There will be new business opportunities emerging with the developing market.

DSOs have an important role in developing the distribution grid to make it possible to meet the environmental objectives and to get the customers active in the electricity market. A key to achieve these goals is to use smart grids. Smart grids are a concept of new grid solutions that basically increase the level of automation in the grid. The smart meter that is capable in hourly-based metering is the heart of the smart grids and it enables connecting small-scale production and demand response; the two example cases that are examined in this thesis work. The question is how to improve the functionality of the electricity market with smart grids. One of the basic economic definitions of functioning market is that there should be enough competition and that taking part to the market is voluntary. With small-scale production the customers would gain more independency from their electricity companies. Electricity is a basic utility without which the modern society could not work so the demand side has not been flexible in the past. With demand response that is enabled by the hourly-based metering the customers can choose when to use electricity. The customers could be steered with the electricity market price signals or with the contractual incentives from the DSO. Sometimes the supplier's and DSO's aims might be contradictory. New products and services could be developed around small-scale production and demand response. It is not clear who is going to develop these. The regulation and legislation also set the limits for the DSO's actions as the distribution is monopolistic business.

This thesis is mainly based on the 25 specialist interviews. The conclusions state that in order to make the small-scale production and demand response improve the functioning of the electricity market the roles of the market actors need to be carefully defined. When analysing the different incentives for small-scale production netting the consumption and the production was found to be the best option. The problem is the tax law that does not allow this. New actors for the market are required to develop the products for the customers as it will not be part of DSO's role. Nevertheless, DSO's should be allowed to invest in smart grids to enable the market functioning. The regulation should be developed to support the investments for smart grids. The new possible services create an interesting opportunity for further studies as well as the real effect of the incentives that are planned for small-scale production and demand response.

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Sähköverkkoala on murrosvaiheessa. Pohjoismaisia vähittäissähkömarkkinoita yhtenäistetään ja sähkömarkkinamallia kehitetään enemmän myyjävetoiseksi, jotta se olisi asiakkaille yksinkertaisempi. Sähköverkkoyhtiön rooli tulee keskittymään pelkästään sähkön siirtoon. Kuitenkin mittaus pysyy sähköverkkoyhtiön vastuulla ja muut markkinaosapuolet ovat riippuvaisia tämän tiedon oikeellisuudesta. Muuttuvat markkinat synnyttävät uusia markkinamahdollisuuksia uusille toimijoille.

Ympäristötavoitteiden saavuttamiseksi ja asiakkaiden aktivoimiseksi sähkömarkkinoilla sähköverkkoyhtiöiden on kehitettävä verkkoaan. Tähän tarvitaan älyverkkoja. Älyverkoilla tarkoitetaan uusia tapoja käyttää vanhaa verkkoa, jota on päivitetty uusilla automaatioratkaisuilla. Moderni sähkömittari, joka mittaa arvoja tunneittain, on koko älyverkkoajatuksen sydän. Se mahdollistaa pientuotannon liittämisen ja kysyntäjouston, jotka ovat kaksi tässä työssä käsiteltävää esimerkkitapausta. Työssä mietitään, miten sähkömarkkinoiden toimivuutta voidaan parantaa älyverkoilla. Yksi toimivien markkinoiden tärkeimmistä kriteereistä on, että markkinoilla on tarpeeksi kilpailua ja että markkinoille osallistuminen on vapaaehtoista. Pientuotannon avulla asiakkaat ovat itsenäisempiä sähköyhtiöistään. Sähkö on perushyödyke, jota ilman nyky-yhteiskunta ei voi toimia, joten kysyntäpuoli sähkömarkkinoilla ei ole joustanut. Kysyntäjouston avulla, jonka tuntipohjainen mittaus mahdollistaa, asiakkaat voivat itse valita, milloin he käyttävät sähköä. Sähkön käyttäjiä voitaisiin ohjata erilaisilla signaaleilla kysyntäjoustoon. Signaali voi tulla sähkönmyyjältä, jolloin se perustuu sähkön markkinahintaan tai sähköverkkoyhtiöltä, jolloin sähköverkkoyhtiö pyrkii tasoittamaan kuormitusta verkossa. Välillä nämä ohjaussignaalit saattavat olla ristiriidassa keskenään. Uusia tuotteita ja palveluita voitaisiin kehittää pientuotannon liittämisen ja kysyntäjouston ympärille. Vielä ei ole selvää, kuka näitä palveluita tulee kehittämään. Regulaatio ja lainsäädäntö asettavat myös rajoja sähköverkkoyhtiön toiminnalle. Uusia markkinatoimijoita tarvitaan, sillä lisäpalveluiden tuottaminen ei kuulu sähköverkkoyhtiön ydintoimintaan.

Tämä diplomityö pohjautuu 25 asiantuntijahaastatteluun. Yhteenvetona voi todeta, että markkinoilla toimijoiden roolit pitää määritellä tarkasti, jotta älyverkoilla voidaan parantaa sähkömarkkinoiden toimivuutta. Kun eri kannustinmuotoja pientuotannolle mietittiin, parhaaksi vaihtoehdoksi muodostui kulutuksen ja tuotannon netottamista käyttöpaikassa. Ongelmana netottamisessa on, että se ei nykyisin ole verotuslakien mukaan mahdollista. Joka tapauksessa jotta sähköverkko pystyisi mahdollistamaan nämä uudet älyverkkojen tuomat palvelut, sähköverkkoyhtiön on investoitava jakeluverkkoon. Regulaation ja lainsäädännön pitäisi kannustaa älyverkkojen rakentamiseen. Jatkotutkimuskohteita ovat muun muassa määrittää, mitä kaikkia palveluita älyverkkojen myötä on mahdollista kehittää ja mitkä ovat parhaat kannustimet pientuotannon liittämiselle ja kysyntäjoustolle.

PREFACE

The topic for this thesis was provided by Vattenfall Verkko Oy. The work also included a visit of 6 weeks in Vattenfall Eldistribution AB in Sweden. The examiner for this thesis was Professor Pertti Järventausta from Tampere University of Technology and the supervisor from Vattenfall Distribution M.Sc. Noona Paatero.

I want to thank Noona and Pertti for their professional guidance and for their patience. I was very fortunate to have you involved in this project. Special thanks to Noona who made my stay in Stockholm so comfortable. I also wish to thank all the people I interviewed in Finland and in Sweden. The conversations really helped to widen my perspective about this topic and the findings from the interviews are in a very important part in this thesis work. My gratitude goes also to the dear colleagues in Vattenfall in Tampere and in Stockholm. Thank you for your advice, encouragement and for the lunch company!

Finally, I wish to thank my family and friends who were supporting me throughout this thesis writing process and who almost let me work in peace.

Tampere, August 18th, 2011

Laura Oksanen

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LIST OF ABBREVIATIONS AND NOTATION

AMR	Automatic Meter Reading
CEER	The Council of European Energy Regulators
CHP	Combined Heat and Power
DSO	Distribution System Operator
EI	Energimarknadsinpektionen, Swedish Energy Market Authority
EMH	Efficient Market Hypothesis
EMV	Energiamarkkinavirasto, Finnish Energy Market Authority
ERGEG	European Regulators' Group for Electricity and Gas
ET	Energiateollisuus, Finnish Electricity Industry Association
EU	European Union
EV	Electric Vehicle
NordREG	Nordic Energy Regulators
OTC	Over The Counter
PHEV	Plug-in Hybrid Electric Vehicle
R&D	Research and Development
RES	Renewable Energy Sources
SCM	Supplier Centric Model
VAT	Value Added Tax

1 INTRODUCTION

The Finnish electricity market was opened gradually to free competition in 1995. The electricity distribution and the transmission were separated from the production and supply. Even the households could change their electricity suppliers starting from the year 1998. (EMV 2010). For the distribution and transmission the customers cannot choose the company as they require monopoly action. Fingrid Oyj owns the transmission grid in Finland and distribution network is handled by about hundred Distribution System Operators (DSO) with their regional monopoly. According to the Finnish Energy Industries (ET) the Nordic electricity market works relatively well (Kauniskangas 2010). The reason for this is that there are many producers in the Nordic countries. Nowadays in Finland there are more than hundred companies that produce electricity, a little less than hundred suppliers and hundreds of power plants. In many European countries the market has stayed centralised despite the opening of the market as there is not enough competition. (Kauniskangas 2010)

The smart grids bring new possibilities to the DSOs to operate their network and to exchange information between different actors in the electricity market. As nowadays transmission system operator (TSO) creates a market place for production and consumption with its transmission grid the DSO should be able to do the same with the distribution grid to small-scale production and consumption. With smart grids the DSOs can handle not only the two-way flow of power but also the two-way flow of information. Smart meters with hourly based metering play an important part here by acquiring and dealing the information. Smart grids are smoothening the way for the renewable energy sources (RES) by enabling the easy connection for distributed generation. In this way the customers can participate to the market more actively when in addition to consuming energy they can produce energy for their own use and sell the rest of it to the grid when they do not need it themselves.

The objective of this thesis work is to analyse how the DSO enables the electricity market in the constantly changing market environment where the smart grids play an important role. The functioning of the market is investigated by analysing two example cases; connection of small-scale production and demand response in Nordic environment, more precisely in Finland and Sweden. First the terms and the working environment are defined. There is an analysis of the current state of the Nordic electricity market and examination how well it goes together with the economical definition for a functioning market. It also has to be defined what smart grids mean in this work and how the smart grid network is different from the current network. The smart grids are seen as a key to achieve the European environmental targets for the so called EU 20-20-20 decision. The current debate about the risks of nuclear power also increases people's interest in energy saving possibilities, renewables and smart grids.

From the specialist interviews the suggestions how to make electricity market function better were gathered. The interviews were executed in Tampere and Helsinki in Finland and in Stockholm Sweden in the winter 2010 and spring 2011. The group of interviewees comprises employees from different units in Vattenfall group and employees from other companies in electricity branch as well as representatives of organisations and energy market authorities both in Finland and in Sweden. The questions how do the regulation and the legislation support the development of the electricity market and smart grids are discussed as well as the need for incentives in developing smart grids. For example the micro generation owners have to pay taxes for the energy they want to sell to the grid which does not make the idea of micro production attractive. The main aim of the work is to analyse the functionality of the electricity market from the scope of connecting small-scale production and demand response and to identify the possible regulatory and legislative bottlenecks in Finland and in Sweden.

When analysing the two example cases of connecting small-scale production and demand response the roles of the main market actors are presented in this context. The supplier-centric model (SCM) where the supplier has the responsibility of most of the contacts and communication with the customer is taken as a background assumption. Nevertheless, the DSO has an important role here acting as an enabler for the whole market where there are several other players. The DSO has to provide the data acquired from the electricity meter to the supplier and the customer in order to keep the market functioning. There could be products and services build around these consumption values so that the customers can easily view their electricity consumption or micro-production and the price of the electricity during a certain hour. This could create business opportunities for the new market players if the consumer protection issues can be sorted out. In this way DSO works as a platform for the market.

Finally the benefits of the smart grids and their effect to market's development are examined. The aim is to find solutions from the point of view of the whole society. The interviewees' opinions about the functioning of the electricity market and issues related to connecting small-scale production and demand response are analysed and compared with each other. Suggestions of how to make the electricity market function better are presented.

There are many aspects considered how the DSO should enable the electricity market. Lots of ideas and problems are brought out but not all the questions are answered here. The objective is to give an overall picture. In addition to the specialist interviews that give the main input for this work the literature and publications of the industry were also used as material to complete this thesis.

This thesis tries to find the answer for the following questions using the two example cases of demand response and connecting small-scale production: How to make the electricity market function better with smart grids? What is hindering the development?

2 ELECTRICITY MARKET

To analyse the functioning of the electricity market it is important to define what market is. Markets are based on changing the goods or services for money. It is a public place where buyers and sellers make transactions directly or via intermediaries. The forces of demand and supply determine the price of the goods in the market. The market comprises the four following mechanisms: determining price of the traded item, communicating the price information, facilitating deals and transactions and effecting the distribution. (BusinessDictionary.com 2010)

2.1 Economical definition of a market

In the market there are numerous players that are all after their own gain. The consumers are after the maximum utility and the producers want to get as high price of their goods as possible. This kind of economy is called decentralized economy. The decision making based on the pursuit of the profit is the great power determining the market. It brings to the economy flexibility, regeneration ability and creativity that are the best benefits of the market economy. To function well the markets require rules of institutions. One of the most important principles is that taking part to the market is voluntary so that the participants join to the market when it is beneficial to them. Other important things that are needed are stability of the financial economy, stable regulation and several rules that are either unwritten or written.

Prices have three important tasks: They communicate the information of the change of the consumer's needs to enterprises and they inform the consumers of the changes in the production techniques. Of course the prices act as incentives, too. The high prices make the consumers save and enterprises more willing to add the supply.

Market mechanism combines the needs of the consumers and producers automatically. Markets function best when there is competition. Then the price is formulated so that the demand meets the supply: All the consumers that are willing to pay a certain price will get the amount of supply that they need to be satisfied, and all the producers that want to sell their product with this price will get their supply sold. In this way the market is in balance. The market always tries to reach the balance. If the price deviates from the balance price there is either excess demand or excess supply situation in the market that makes the freely changing price set back to the balance state. Excess supply creates a downward pressure on the price level and excess demand upward pressure on the price level (McEachern 1988. pp 62 – 63). The economy is build of the decisions of the individual units. The actions of these units are expected to be rational and predictable as the enterprise units are supposed to sell their goods with the highest gain they can get and the consumer units are supposed to be after the maximum utility. (Pohjola et al. 2007. pp 31 – 37)

The differing views of the consumers and the suppliers are sorted out in the market. Markets lower the transaction costs such as bringing the buyer and the seller together, finding what is sold and how the goods compare with other goods. In short, this means the cost of time and the information required for exchange. The market brings together the market demand and the market supply curves. The point where the curves intersect is the equilibrium point as can be seen from the Figure 2.1. This point defines the price and the quantity. When this point is reached both the consumers and the suppliers are satisfied and there is no need for the price or the quantity to be changed. (McEachern 1988. pp 60 – 61)

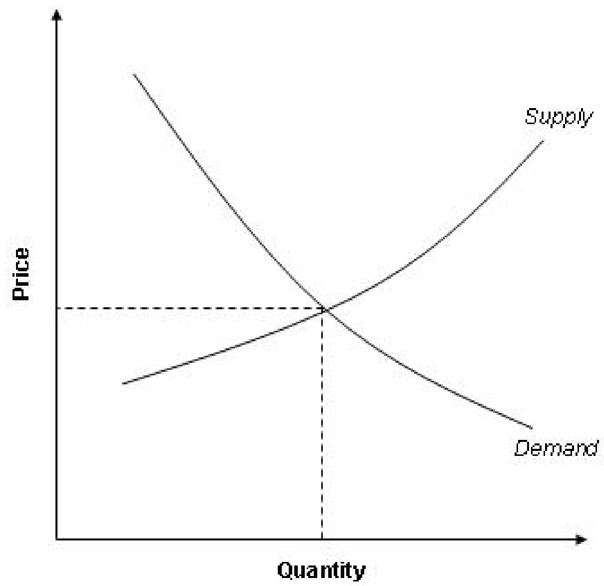


Figure 2.1. *Demand and supply curves (Nolet 2007).*

There are also some defects in this kind of system. The people with more money are in a better position than those with little money. Also if the parties in the market only think about their own interest the consequences they impose to other parties might be neglected. For example a company might produce goods and pollute and destroy the environment meanwhile. (McEachern 1988. pp 60 – 61)

2.2 Functionality of the market

The rules of the perfect competition are very strict and it is difficult to make an example of a market that functions perfectly. For a competition to be perfect there have to be numerous buyers and sellers in the market so that the market share is small for everyone. The goods that are sold should be of the same quality and everybody should know the properties of the goods perfectly. In this way it does not matter whose product the buyer buys. There is only one price for a certain kind of product so no buyer is willing to pay more than the market price and it would not be wise for a seller to sell with a cheaper price. In addition there has to be free access to the market and one should be able to leave the market when ever. The right or the possibility to produce the goods should not be limited in any way. In this way the large gain in some market area attracts more competitors there which equalises the differences in income. In a long run in perfect competition in all the fields of the market the gain is equal. (Pohjola et al. 2007, pp 37)

The basic hypothesis of the economics is that competition is the key for effectiveness (Pohjola et al. 2007, pp 116). Nevertheless, competition is not always perfect and sometimes competition is impossible all together. The public services' market as public health care is an example where the competition is not working properly. The service is taken care by the government and is paid with tax income. In this kind of market government also gets involved in the market either because it believes that the people do not make reasonable decisions or in order to improve the functionality of the market. Sometimes the intervention of the government improves the welfare and sometimes not. The two distinguishable market structures that are far from being perfect are oligopoly and monopoly. The previous means that there are only few participants in the market. The latter means there is only one supplier in the market. When there is only little or no competition at all in the market the sellers can decide the price of their goods arbitrary. In this way the market is imperfect and twisted. Sometimes the monopoly is a logical solution as in electricity transmission and distribution in which the market is called a regional monopoly as it would not be reasonable to build parallel electricity lines for all the competitors. (Pohjola et al. 2007, pp 31 – 37)

Unlike in competitive market in monopolistic market the producer can gain supernormal profits. In competitive market in long the run these kinds of profits would be eliminated because the large profits attract more entrants to the market. The price the consumer finally pays is higher than if the market was competitive as the monopoly has no fear of the possible entrants offering products with cheaper price. A monopolist produces less than a competitive industry and charges a higher price. (Begg et al. 2005, pp 133 – 135)

The effectiveness of the market can be measured with Efficient Market Hypothesis (EMH). According to EMH in the efficient market the prices reflect the available information all the time. The suppliers and buyers adjust the product price immediately according to the new information available. In this way the market efficiency can be measured in how quickly the information is reflected to the price of the product. The efficient markets are crucial in order to achieve the economic goals. The efficient market assists in relocating of the resources, providing better production and consumption of goods and services and maximising benefits at minimum cost through competition. By taking this into account it is important to measure the efficiency of a market in order to be able to make the market more efficient. (Zhe Lu et al. 2005)

EMH can be divided into three cases: weak EMH, semi-strong EMH and strong EMH. In weak EMH the current stock prices fully reflect all the market information as historical sequence of prices, rates of return and trading volume data. This is public market information. As all this and security market information is already reflected in the market prices the hypothesis implies that the historical market data has no relationship with future rates of return. The semi-strong EMH implies that security prices adjust quickly to the release of all public information. The semi-strong EMH includes all the information of the weak EMH as all that information is public, but it also includes all the public non-market information, such as the news of economy and political news. In this way investors who are making decisions based on any important information after it is public should not derive above average risk adjusted profits from their activities. In strong EMH stock prices fully reflect all information from public and private sources so that no investors have monopolistic access to information that could be relevant to the price changes. Strong EMH encompasses both the weak and semi-strong form of EMH. This means that in an efficient market all information consistently incorporates in determining prices. In addition, all information should be freely accessible to all the market participants and all the participants should have equivalent resources to analyse the information and they should follow the development of the market as intensely all the time. Therefore in a long run, no market player would earn more than average profits in the market as the market prices do not follow any systematic pattern that could lead to excess profits for some market participants. (Zhe Lu et al. 2005)

2.3 Functionality of the electricity market

Electricity market works according to the same principle as other markets too: The demand and supply define the price. Nevertheless, there are few curiosities related to the electricity market that other markets do not have: Electricity cannot be stored; at least not yet in a big scale, and electricity is a necessary commodity. The modern society could not work without electricity. Modern houses work with electricity. It is used for preparation of food, heating and for using various electric equipment. Industry uses lots of electricity for manufacturing of goods. In this way companies and individual customers need to participate to the electricity market whether they want or not because otherwise they could not survive in everyday life within the standards of the western countries. The consumer purchases electricity what ever the price is. Nevertheless, this might come to change in the near future because of the distributed generation that enables people to be more independent from their electricity company as they have the chance to produce their own electricity. Demand response where the customers can move their consumption to different time according to some steering signals like electricity market price or capacity of the distribution network will also bring the electricity market closer to a normal functioning market where the price is set by the demand and supply. Small-scale production and demand response will be discussed in more detail in next chapters.

In the Figure 2.2. the picture a) represents a functioning market where the price is determined at the intersection of the demand and the supply curve. However, in the picture b) the demand curve is twisted as there is always demand for electricity and traditionally people cannot choose not to consume it. The curves intersect there where price is higher than in the idealistic market. This way the electricity consumers do not see the real price of the goods. They have not had the necessary technical tools for this or there has not been any economical incentives to react. (Kekkonen 2011)

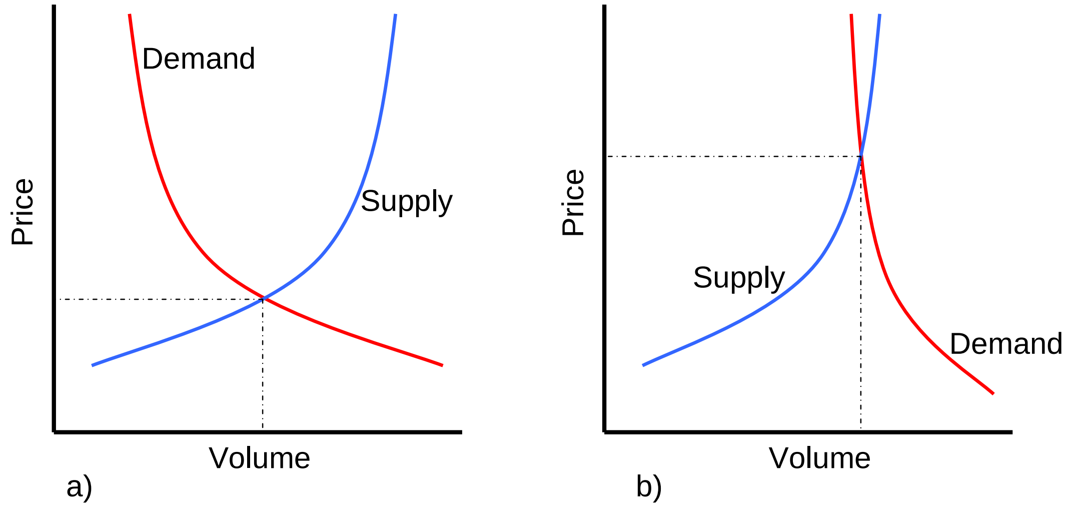


Figure 2.2. *a) Demand and supply in the ideal market. b) Demand and supply in the electricity market. (Kekkonen 2011)*

In Nordic countries the electricity is exchanged in the common Nordic market Nord Pool that was founded in 1993 in Norway. Nowadays the participant countries are Finland, Sweden, Norway and Denmark. The physical electricity market is divided in Elspot and Elbas markets. In Elspot the price and quantity curves are set by supply and demand for the next day, for each day of the year. The smallest unit for trading is 0,1 MWh / h and the bids can be done for one hour or a bloc of hours. A bid consists of combination of desired volume and price. Elbas is a continuous after-market for the Elspot market. The price for each hour is set one hour before the realisation of that hour. The smallest trading unit is 1 MWh / h. In addition to the physical market there is derivative market for financial products such as futures, forwards and options. The purpose of the financial market is to hedge against the price volatility of the physical market. The Elspot price is the reference price for the derivatives market, Over the Counter (OTC) market and balance market. In OTC market the trading is done between two parties so that the electricity does not go through Nord Pool. The OTC market trade can be physical electricity trading or trading of derivatives.

Nord Pool's tasks also include clearing operations and market information delivery. In the Figure 2.3. the products of the electricity market are illustrated. (Partanen et al. 2005)

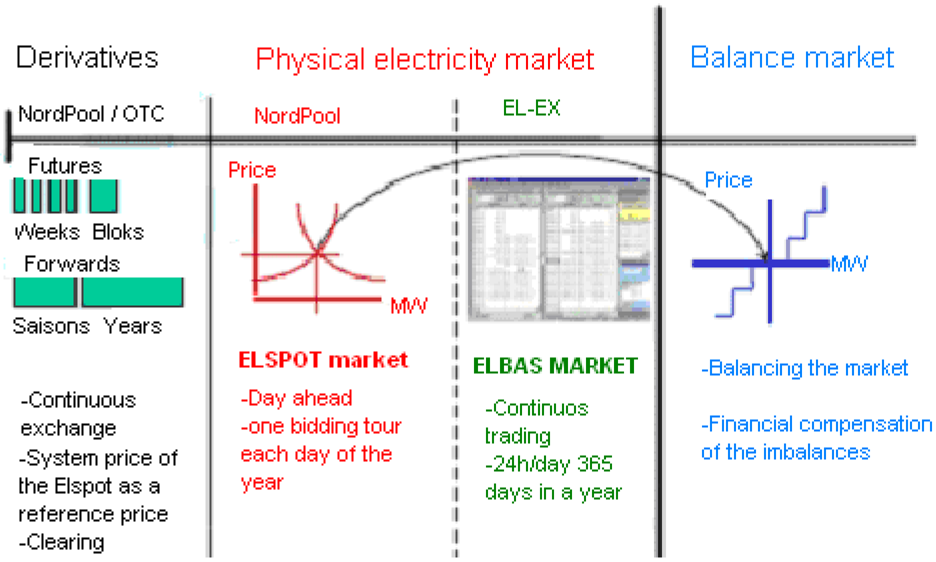


Figure 2.3. *The products of the electricity market. (Partanen et al. 2005).*

In the electricity market the price varies according to the time of the day, month and year. In 2010 74 % of the electricity is traded in Nord Pool in Nordic level (Nord Pool Spot 2011). In Finland this number was 55 % in 2009. The volume in the market is increasing year by year. The rest of the electricity is traded in OTC market, from the power plant directly to the local enterprises or to households. The market price is often used as a reference price for the deal. The company can sell all or part of the electricity it produces to the customers with fixed price contracts. If the demand exceeds this the company can buy the rest of the electricity from the electricity market. Some of the electricity companies sell the electricity to the market from where the supplier company of the same concern buys it for selling to the customers. The strategies for selling and buying vary a lot. The fact that about 70 % of the electricity companies are owned by the community and work as a solid part of the communal economy also bring some peculiarity for the market. A communal electricity company can have a major role in bringing income to the community’s industrial policy. (Sallinen 2010)

In overall, the Nordic electricity market works well. It has been seen as a model for the rest of the Europe. (ET 2011). Nevertheless, there is always place for improvements. Some of the suggestions that are collected from the interviews are presented in the Chapter 7.

The demand of the electricity is also very much dependant of the weather. Normally during cold winters the price of the electricity rises in the Nordic electricity market. The winter of 2009 – 2010 is a good example of this. Then the price of the electricity rose up to 1400 €/kWh for couple of hours. The average of the year was 37 €/kWh. The reason for this price peak was that the cold period had lasted exceptionally long in all the Nordic countries simultaneously. The demand for electricity grew faster than the power plants could produce. The need for heating electricity rose suddenly. At the same time the half of the Sweden's nuclear energy capacity was out of use and there were faults in the transmission line between Sweden and Norway. (Sallinen 2010)

As it is difficult to forecast the weather it might be difficult to foresee the sudden changes in the electricity consumption and react to them fast. Suppliers can protect the electricity price with derivatives by locking the buying price of the electricity to the current price in the electricity market for a certain period of time. In this way the price peaks in the electricity market would not affect the electricity prices for the customers. Normally the suppliers protect the electricity they are about to sell only partially. This is why in a long run the peak prices have some influence on the customers' electricity bill, too: When the price is high in the market also the prices of the derivatives get higher. (Sallinen 2010). This is discussed more in the Chapter 6.2.

To smooth down the price peaks additional supply is needed. New power plants could be built as more there is supply available the more stabile the prices are. Nevertheless, building power plants is quite slow process. On a short term the demand response is feasible. That means that the consumption is reduced temporarily or shifted to the near future to another period of time. Especially the industry has used this trick for a while now. When the price is high in the electricity market the industrial processes are switched off or the production is temporarily reduced. This way the demand of the electricity is reduced which cuts down the peak prices. If the industrial company has its own production it is profitable to sell it to the electricity market during the peak hours. The DSO and the customers should improve their cooperation so that the advantage of the demand response could be increased. (Sallinen 2010) This is possible because the spot prices for the next day are known. Hourly based metering enables the demand response for the small customers too if the customers have a price tariff that is based on the spot prices. (Hänninen 2011) If the demand is reduced the prices reduce too. The system is self-regulating and that is what makes it a market.

As the price adjusts according to the demand and supply the efficiency of the market can be measured how quickly the new information affects the prices. The electricity market should also work like this so that the price efficiency benefits all the market participants, through the electricity distribution chain up until the customer. The accurate and fast price signaling encourages the consumption and supply and attracts new investments. Zhe Lu et al. examined the Australian electricity market efficiency with Efficient Market Hypothesis (EMH) in 2005. As in the electricity generation sector the only variable cost in short run is the fuel cost, the analysis is drawn based on how fast the fuel price changes were reflected to the market prices of the electricity. All the other costs such as materials, labor, interests, taxation and stockholder capital costs are fixed over a short run. The Australian electricity supply consists of two major parts: the base load is provided by coal-fired power plants and the gas fired power plants work as peak load providers. The electricity market clearing price is set by the highest bidding price of the last part of the electricity supplied. When the clearing price is set by the gas-fired generators the correlation between the gas prices and the electricity price could indicate the market efficiency. In this way the fluctuation of the gas price should largely influence the electricity market prices. Positive correlation between the spot prices of gas and electricity in most occasions was observed in the analysis. Even though the correlation was weak form of EMH it still can be used for market design, operation and portfolio management which is a common tool for the risk management in market environment. (Zhe Lu et al. 2005)

2.4 Characteristics of the Nordic electricity market

The market model defines the responsibilities of the electricity market actors. That is also one of curiosities of the electricity market that the roles have to be very clearly determined in order to give a signal that the market is working transparently so that the customers understand the responsibilities of the different actors. Clear division of roles also facilitate the daily operations of the actors as they can work according to the processes in a cost efficient way and minimise the exceptions in their actions. Different tariff structures will also create new possibilities to steer customers to use electricity in different ways in order to cut the consumption peaks in the electricity lines or to influence the electricity market price peaks. The Nordic electricity market is divided to price areas because of the bottlenecks in the transmission system. The price areas also give some complexity to the market structure.

2.4.1 Market model

At the moment a dual-point contact model is in use in Finland and in Sweden. There both the supplier and the DSO have a contact with the customer. Customer also receives two separate bills from them normally. If the customer does not choose the supplier the electricity will be supplied by the supplier of the last resort and then the customer receives only one invoice. Nordic countries are the only place where the dual point contact is in use. The Nordics are the early adapters to the unbundling as the rest of Europe is little behind in adapting the concept of regulated and deregulated part of the market (Söderbom 2011, interview). The problem with dual-point contact model is that customers do not understand the difference between the supplier and the distribution company and feel that this model is complicated. To make it more simple for the customers there has been talk about supplier centric model (SCM).

In SCM the customer would have in most of the cases the supplier as the primary contact. The DSO would work in the background and be responsible for purely DSO-specific questions. There has been a need for this kind of model as some of the customers in Sweden have changed back to their previous supplier just to receive only one invoice instead of the separate ones from the supplier and the DSO. If the customers buy the electricity from the same group as where they have the DSO they have only one bill. (Svalstedt 2011, interview). However, for example Vattenfall Verkko Oy in Finland already offers the suppliers the possibility to produce a common invoice to the customer. It is not still clear to what extend the model will be implemented. At the moment the energy market authorities in the Nordic countries (NordREG) are considering the different market models and nothing has been decided yet about which model to implement (Värilä 2011, interview). In this thesis work we take the SCM as background assumption as it is likely to come in the future at least to some extend.

The main advantage of SCM is that it would make things easier for the customer as there would be only one interface to contact. Then customer would receive only one invoice even though he had changed the supplier. On the other hand, if customers had only one bill then it would be even harder to understand the difference of the DSO and the supplier (Svalstedt 2011, interview). Still the distribution and supply would be mentioned separately in the invoice. For the DSO the advantage of this model is that there would be no need to store and maintain all the invoicing information of the customers but only the invoicing information of the suppliers. In SCM the DSO invoices the suppliers and the suppliers handle the customers' invoicing. In this way in Vattenfall Verkko Oy's case in Finland the company needs to have only about hundred suppliers' invoicing contacts instead of having almost 300 000 customers' invoicing contacts. This would save resources. (Karjalainen 2011, interview). As well as the customer service can be of a lighter structure than nowadays. The DSO will be the primary contact for only the network specific issues such as new and changed connections, technical metering and network issues or outages. This also saves some costs. (Rud 2011, interview)

This model has also some challenges from the DSO's perspective: The electricity meter data needs to be reliably delivered and stored so that the suppliers can use it for invoicing. The DSO's role in metering will emphasise still. In the future data needs to be delivered faster and faster which creates problems in validation of the meter values. In Sweden the values need to be collected once a month and the reading rate is 99,7 % which is very good. On a daily basis it might be difficult to obtain as high percentage. In the future along with the harmonisation of the Nordic electricity market the metering values could be stored for central data base from where all the suppliers in the Nordic area could find them. (Nääs 2011, interview)

In the new model it is important to have clear idea how to share the responsibilities. It could be that the supplier does both the electricity supply contract and the network contract with the customer. Supplier also handles the moving situations and invoicing. The rest of the tasks such as tree felling, cable showing and outage service will be on DSO's responsibility. One thing that could also simplify things for the customer is to have only one contact phone number presented in the bill with which the customer can reach both the supplier and the DSO. By clicking the number one or two on the phone the customer could choose if he wants to contact the supplier or the DSO. At the moment because of the obscurity of the roles of the supplier and the DSO the customers call to wrong numbers from time to time. (Värilä 2011, interview)

In SCM where the supplier has most of the contacts to the customer the role of the outage service should be defined, too. It is crucial that DSO will have the role of keeping the information needed what it takes to maintain the network and the outage service. In some of the considered variations of the model it is possible to have the outage service and outage message transfer outsourced so that it would be taken care of by some new market player. This new entity would also take care of all the fault services of all the DSOs. It would not be cost efficient and it would not help develop the network for example the outage message transfer or investing in smart grids as there would be only a standard that the service tries to meet in a minimum way. At the moment the DSOs in Finland are in a very different level on outage service so outsourcing the outage services would be complicated. This would also increase the costs which could be seen in the customers' electricity bills. DSO needs the meter point information in order to handle the outage service. The outage service brings added value to the services of DSO and as the AMR that is an essential part of the outage repairing service it would be rational to maintain the outage service as one of the responsibilities of the DSO. When having the point-to-point connection to the customer's meter one can see fast if the meter can be contacted or if there is an outage or the meter is broken. (Karjalainen 2011, interview).

2.4.2 Tariff structures

As the electricity supply and the distribution are unbundled the customer sees the cost of them separately in the electricity bill. There are different tariff structures for both of them. The supplier's part consists of small fixed fee and the consumption measured in kWh. In most of the cases, also the distribution's part includes a fixed fee and the energy in kWh:s but there are also some companies that use power based tariffs already. In Finland and in Sweden the fixed part is relatively small compared to the energy part. The fixed part varies according to the connection point. In the rural areas it is more expensive than in cities because building the grid in country side and maintaining it is more expensive as the distances are long. The DSO has to do regional pricing within one consistent concession area, a geographically integrated area, the prices have to be the same for all the customers. However, in non-connected concession areas the prices can differ between city and the rural areas. This means that DSO's business is so called discriminating monopoly as the price of the electricity is different for different customers. This goes against the principle of perfectly functioning market as there the price of the product should be the same for all the buyers. (Begg 2005, pp 137). Customers have difficulties in understanding this and so different pricing structures have been considered. For average household customer the cost of the electricity transmission including the taxes represents 44 % of the total price. This share the customer cannot influence by changing the electricity supplier. In the Figure 2.4 the formation of the price for an average household is presented.

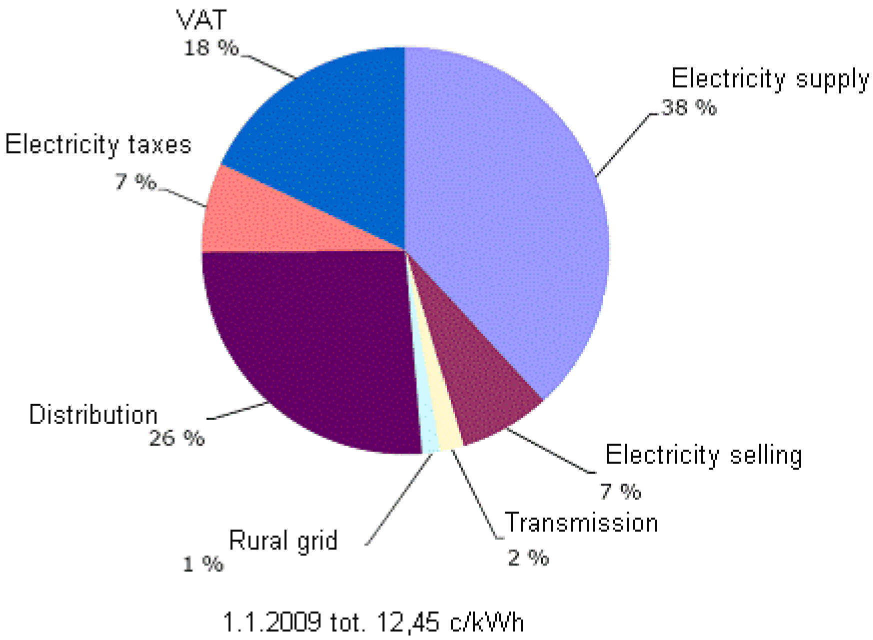


Figure 2.4. *Formation of the electricity price for a household in Finland in 2009 (ET 2011).*

In this thesis work the pricing models for the distribution's share are under discussion as they enable the steering of the customers in demand response. It is very likely that the future's electricity tariffs will be more close to the market prices of the electricity. If the demand is reduced the prices reduce too. The system is self-regulating and that is what makes it the market (Söderbom 2011, interview). Still the industry has been interested in having fixed fee for the distribution. The common Nordic electricity market drives probably towards more similar price structures in Nordic countries. The extreme options as having completely fixed distribution fee or totally energy consumption based distribution fee can be difficult to have in the future. Introducing new price structures might also be difficult as customers have low interest in energy issues, though the recent debate about the environmental and climate issues could help to raise the awareness of the domestic customers. (Vattenfall, Framtida prisstruktur 2010)

There are many reasons that speak for fixed fee in distribution. About 95 % of the DSO's costs are fixed so it would be more logical if the price of using the grid would be fixed for the customers, too (Hänninen 2011, interview). For the customer the advantages of the fixed fee are that it is simple and easy to understand and also to budget as the price is always the same. In that way also understanding the difference between the supplier's fee and the DSO's fee would be easier. The tariff should be constructed so that it would be fair for everybody and not discriminating. There are of course defects in the fixed fee of distribution, too. For example, a summer cottage customer who stays at the cottage only part of the year and heats it with wood could feel to be treated unfairly if he had to pay the same amount of fixed fee as some customer in a cottage with electricity heating and living there all year around. The customers need to be classified somehow in order to make the system fair. With the new smart meters the power limit could be set in a more flexible way and not just the basic Finnish fuse sizes of 16, 25, 35, or 50 A for small customers. Then there should be a "fine" if the customer takes higher power from the grid than agreed. (Hänninen 2011, interview). On the other hand, the classification of the customers is difficult and then there is the risk of having too many classes. The administration and the customer service would become complicated. It depends where the customer is living and maybe it is easier to handle a tariff that has two or three parts than numerous categories for customers. (Rud 2011, interview). In addition, probably the customers do not want to pay for something they do not use. On the other hand, the nature of the fixed fee in distribution is very much similar as of the internet broad band. People are not using internet continuously but they still pay fixed fee for it. Customers do not question that at all. Why should the electricity distribution be any different from this? On the other hand, when the spirit in the electricity branch is very much pro energy efficiency the fee that allows the customer to consume as much as he wants to with the fixed fee seems odd. But then the pure electricity transmission's and distribution's part form the customer's electricity bill is actually about 30 % as can be seen from the Figure 2.4. so it would not be in contradiction with the energy saving policy. There would still be the supplier's part which encourages saving energy as it is directly connected to the amount of electricity that is consumed. The steering signal may not necessarily be strong enough for all the customers if there is only the supplier's part that varies according to the electricity consumed. In addition, the fixed fee would be in accordance with the idea that the DSO's turnover should not be dependant of the amount of electricity that is being consumed. In this way the DSO would have a credible role in advising people in the energy efficiency matters. It does not encourage trust if the advising has influence in the turnover of the company. These facts support the fixed fee of distribution or at least higher share of that. (Hänninen 2011, interview).

In totally energy consumption based tariff the advantages are that the customer pays only for the electricity he uses which seems fair as he can influence his costs directly. It also gives more incentive to energy efficiency. (Vattenfall, Framtida prisstruktur 2010). This way the customer could be steered with the price and got to participate in demand response. For larger industrial customers with greater than 63 A fuse they already have power tariffs and in that way the demand response exists already.

Then there has been interest from the DSO's side towards power based tariffs rather than energy based tariffs. The customers would pay for the actual use or the maximum load they take of the grid. The power tariff would still include the environmental saving aspect as the gas or oil fuelled peak power plants do not need to be used if the load in the grid is low and the load curve stays more flat. With energy efficient equipment the customer could save money and the environment. The power tariff would be some sort of time tariff with more variation than just two-time tariff that is currently used in Finland and in Sweden. For grid's sake the power based tariffs seems interesting as with them the quality of supply could be improved and investments could be postponed or avoided completely when the overall load is more flat in grid. The biggest issue is to get customers approval for this. Power measured in kW:s is obviously more abstract and more difficult to understand than energy that is measured in kWh:s. (Hänninen 2011, interview). In Sweden the power tariffs have been tested in form of measuring the three highest consumption values in a month and calculating the average from them and there are even companies, such as Sollentuna Energi that have been using power based tariffs for years. The fixed share of the DSO's bill for small customers is set based on the fuse size and now the possibilities of changing this share to more actual power based fee have been considered. Replacing the fixed fee that depends of the size of the fuse with power tariff would be a way to get rid of the old fashioned fuse size dependence. The fuse is only the protection that prevents the customer from burning down the house. (Englund 2011, interview)

Before the high price peaks of the winter 2009 - 2010 there was a shift towards more dynamic prices but then after the price peaks more flat-rate tariffs were wanted. Even though price peaks do not influence directly to the customer as they are not completely exposed, they still have been reacting and moving back to more stable contracts. (Kolessar 2011, interview)

The customer researches indicate that people prefer tariffs where they can influence more to the size of their own electricity bill. In addition, more varied use of the electricity grid in the future with small-scale production and demand response requires more flexible tariff structures. (Vattenfall, Framtida prisstruktur 2010). It has also been found out that when testing the tariff structures that consist of totally fixed or totally consumption dependant part it always comes to that of having both parts in the tariff is the best option. (Willerström 2011, interview)

2.4.3 Price areas

The Nordic electricity market is divided into price areas. In Finland there is only one price area, two in Denmark, five in Norway and Sweden that used to be only one area will be split to four areas on 1.11.2011. The function of this areal division is to solve bottlenecks in the transmission of electricity. (Richert 2011, interview). The bottlenecks are formed when the physical capacity of the transmission lines is not enough and the production and the consumption are not spread equally inside the area. When there is scarcity of the electricity in some area it is not possible to use the electricity from the areas where there is plenty of it, as planned in the first place. This happens because the electricity cannot be transmitted. It is also possible that when there is excess in production of electricity in some area there is no capacity in the transmission network to accommodate it.

The lack of capacity might be harmful for developing renewable energy sources if the energy cannot be used even though it is needed elsewhere. In Denmark and in Germany the inadequate transmission capacity combined to the fact that the large amount of electricity produced with the renewable energy sources increases the volatility of the price have led to negative prices. When the electricity that is produced with renewable energy sources is prioritised to be fed in to the grid the base power plants like nuclear power plants that cannot be regulated still have to be driven with the maximum power. This leads to excess in supply of electricity for a moment. Then the price of the electricity goes negative as for the producer it is still cheaper to pay to the customers to use electricity than to use the power plants in half capacity or to stop them all together. This is not cost effective or economically wise to the society. Nevertheless, using the fuel with non-optimal way or changing the level of usage of the nuclear power plants might damage the equipment. (Koskelainen 2011, interview). Negative prices give confusing signals to the customers. When people are normally told to economise and save the energy and the resources, now they are paid to consume more. In addition, giving a negative price to a valuable product seems very odd. (Nilsson, M. 2011, interview). In Nordic electricity market the bottlenecks are tried to be solved with splitting the areas to different price areas. In different price areas the supply and demand decide the price on each area separately.

There are two solutions how to solve bottlenecks: counter trading or market splitting. Traditionally in Sweden to avoid bottlenecks from showing in the prices counter trade within the country was done and export and import were used to balance the bottlenecks. In counter trade on the side where there is lack of electricity the generators are paid to generate more. On the other side of the price area cut where there is excess amount of electricity the generators are paid to cut down the production in order to keep the supply and demand in balance. This way the bottlenecks are solved artificially by pretending that there is no bottleneck and in the end this seems to the market that there is the same price throughout the country. This gives the illusion to the consumers that there is no scarcity of electricity. The producers see that because they are paid to act but the consumers do not. For generators' side it is the same as if the country was split into price areas but the normal consumers do not see the real prices. In addition, if it is not allowed to turn off the cables to Denmark and when there happens to be large demand in Denmark's side the counter trade is done in Sweden and eventually it will be the tariff payers who are paying the costs of counter trading. Dividing the country into price areas gives the right market signals. It increases the understanding where the more generation or more consumption is needed. It gives right signals to build more electricity production to the south than to the north. This gives an incentive to build small-scale production to the south of the country where it is needed. (Nilsson, M. 2011, interview)

The new division of the Swedish area prices has evoked some conversation. In the first place it was done because of a decision from EU. When Sweden was one price area and there were bottlenecks in the system the bottlenecks were moved to the borders. This meant that Denmark had to suffer from the scarcity of electricity until the bottleneck was solved in Sweden. Because of the Denmark's complaint that Sweden was not complying with the competition rules Sweden decided to form the four price areas to solve the situation. In addition, restricting trade is never a good solution as it leads to non-optimal use of the resources and can cause serious damages to the industry in the long run (Nilsson, M. 2011, interview). It was Svensk Kraftnät, the Swedish transmission system operator (TSO) who decided the cut lines for the areas according to technical and geographical points of view. (Kolessar 2011, interview)

2.5 Summary

Market is formed by a large number of profit driven individual actors who act independently. The price is determined there where the demand and the supply meet. The key of the functioning market is competition. In order to improve the competition there ought to be many producers in the market so that there would not be any dominant producer who could affect the price of the good with its actions. In the electricity market this problem could be solved by increasing the electricity production units by favouring the small-scale production.

As electricity is a common utility the demand curve of the electricity market is slightly twisted. With the help of smart grids the new methods to use electricity for demand response could improve the functioning of the electricity market when the demand side starts to react to the electricity market prices, too. To make the demand response possible the market information should be available the customers in a form that they can react to it. Accurate price signalling is the key factor in indicating and improving the market efficiency because it not only shows how efficient the market is but also encourages new investments.

The purpose of the supplier-centric model (SCM) is to make things easier for the customer. The risk is that then the customer will totally lose the concept of separate supplier and DSO. New price models are being planned in order to simplify the tariffs for the customer and in order to charge the customers more fairly and so that the tariffs are more correlating with how much electricity the customers actually use. There has also been interest towards fixed fee for the distribution’s share as it would match more with costs of the DSO. The price areas also influence the price the customer pays in the electricity bill. The price areas are used to handle the bottlenecks of the transmission capacity. The customers living in different areas have to pay different amount of money of the electricity they use which is in contradiction with the principle of functioning market where the price of the good is supposed to be same to all the consumers. On the other hand, it can be seen that there are the transportation costs included in the price of the electricity and the price areas also give correct market signals to build more production there where there is more demand.

3 NEED FOR SMART GRIDS

In 2007 the European Council approved the energy saving programme 20-20-20 in order to prevent the climate change. This means that the greenhouse gas emissions need to be reduced by 20 %, the share of the energy produced by the renewable energy sources should be increased by 20 % and the consumption of energy reduced by 20 % by improving the energy efficiency. (European Commission 2011). Energy efficiency is expected in regulation 2016 in Sweden as incentives. However, long depreciation times might limit the effect in showing in the infrastructure before the year 2020. The directive suggests that the measures for saving with demand response and distributed generation should be reflected in the network tariffs. (EU - Energy efficiency directive, draft 2011)

The demand for smart grids is undeniable: The whole society works with electrical equipment. Customers want better quality electricity without interruptions. Climate change control necessitates more energy efficient use of the electricity. The smart grid network can anticipate high peaks of consumption and it can repair itself by using automation. It is reliable and safe. (Europaeus 2010)

3.1 Smart grids

Smart grid can be defined as a grid that intelligently brings the consumers and the producers together. It allows the power to flow to both directions. The energy consumption will be reduced but the electricity consumption will grow which is based on the fact that with electricity many fossil fuels can be replaced. (Hänninen 2011). Smart grids are needed to integrate increasing amounts of decentralised generation, electric vehicles and heat pumps to the grid. The direction of the power flow in the distribution network will change according to the energy reserves and market price. In addition, smart grids are the way to encourage consumers to participate in managing actively their energy demands. It is not a purpose as itself just to make the grid smarter because of wanting to have the newest techniques in the grid but the smart grids are the key to meet the EU 20-20-20 objectives (Hänninen 2011, interview). They facilitate the penetration of the renewable and the decentralised generation at the same time as operational security, power system and electricity market efficiency improve. They provide the customers the possibility to participate actively in the market not only as more aware buyers but also micro producers with wind, solar or micro bio-combustion power. The electricity could be stored to electric car’s battery and the then the customers can sell back the excess energy when they does not need the energy for themselves. Smart grids will also enhance the

DSO's grid operational tools and eventually reduce network losses. (EURELECTRIC, pp. 5; 8)

In order to have smart grids as part of the electricity system there should be these three drives: regulation, technical development and customer's expectations as presented in the Figure 3.1. These three interact and influence the changes that are necessary to make to the market function better. For example, a customer could find out about a new technical solution and decide that he wants this kind of service or product. Then the other market participants have to make it work with everything else in the market. There is also the other connection between the customer and the regulator: If customer feels that something in the market is not working he might consult the regulator and as a result of this the regulation might change. Then the DSO and the other market actors have to adapt to this change. The market participants always have to be able to adapt to the change of the technology and the regulation. (Lindgren 2011, interview)

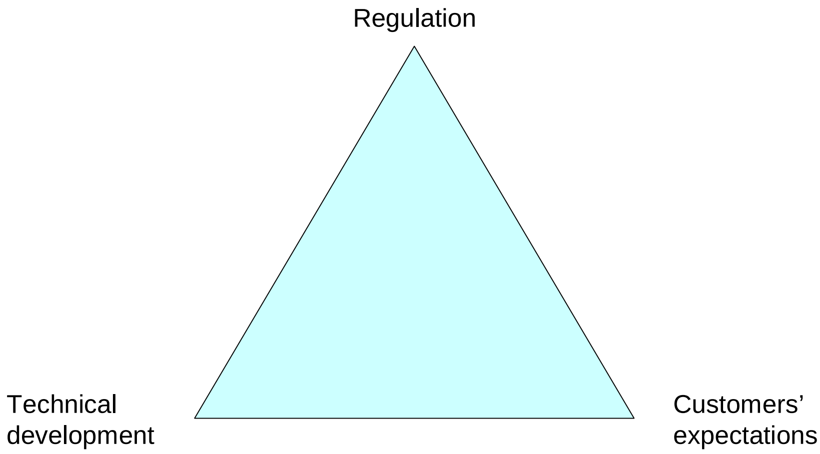


Figure 3.1. *Requirements for developing new network solutions.*

The objective is to create an economical, strong and delivery reliable distribution network. There is already some intelligence in the distribution grid: the modern electric meter that can measure the electricity consumption values in hourly bases already gives the possibility to optimise the operation of the network. In the Figure 3.2. the possibilities for smarter usage of the electricity grid are presented. The smart meter is in the centre of the picture as it is a prerequisite for all the points mentioned around it. (Hänninen 2011)

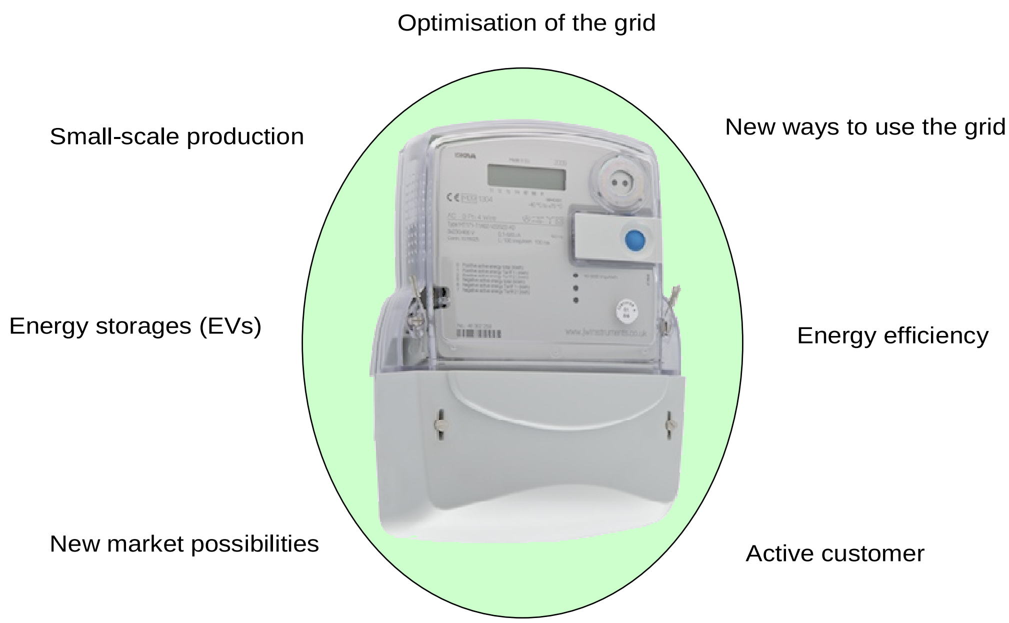


Figure 3.2. *The possibilities smart metering creates (Hänninen 2011).*

For the customer the most visible part of the smart grid is the electric meter, the smart meter. It connects the customer to the smart grid network. Changing to smart grid is a long term process and will not happen in one night. In 2014 when the hourly-based metering is taken into use Finland will be the leading country in developing the smart grids. As an investment the installation of the smart meter to every household is of the same order as the electrification of the country side was. This will have some influence on the prices of the distribution but the network would need reparation anyway and investments are necessary for the delivery reliability. (Europaeus 2010)

The smart grids are natural phase of evolution in the network development. They have been developed for long already in Finland that is a leading country in this matter. Basically it means adding the level of automation. The centre of the smart grids is the smart meter whose roll-out has taken off very well after the statement. In addition to measuring the energies it has an important role in the outage service, defining the quality of electricity and in the compensation of the damage cases. The development of smart grids has been necessary here as most of the land is rural areas where the distances are long and the automation is needed. It has been difficult to send contractors to the spot to see what is wrong. The development of the automation and remote control has been cost-effective and the harmonisation of the systems is advanced. (Myllymäki 2011, interview)

The smart meter will provide customers with more accurate information about their consumption. As the customers become more aware they can use electricity in a more efficient way. Smart meters can also be used to localise the fault as is already done by some DSOs. A future scenario could be the following: a hard wind sweeps across the Northern Europe. The wind power will be distributed in a common European electricity network. The smart electricity systems at customer's housings will react to the cheap price of the electricity and start charging the battery of the electric vehicles (EV) and heat the water in hot water supplies. Meanwhile also the hydroelectric plants are used to pump the water to the pools so that after the wind has passed the hydroelectric plant can work to produce the maximum power. The households are able to sell electricity, too. In that way the solar panel is useful also during the times when the house is not using the electricity for itself. The whole society benefits from the smart grids as the energy efficiency improves, the stability of the network increases and the electricity market functions better. (Kauniskangas 2010) A change from the conventional electricity grid to a smart grid can be seen in the Figure 3.3. In the conventional grid the power plants were big central power plants from where the electricity was distributed to the consumers first with high voltage transmission lines, then medium voltage and finally low voltage lines. The power flow was one-directional, so to speak. In smart grid system the production of the electricity can be connected to which ever voltage level. The ways of producing electricity are more varied and more environmental friendly than in the conventional system. The operation is based on real time data and the power flow is multi-directional and controllable (Söderström 2010).

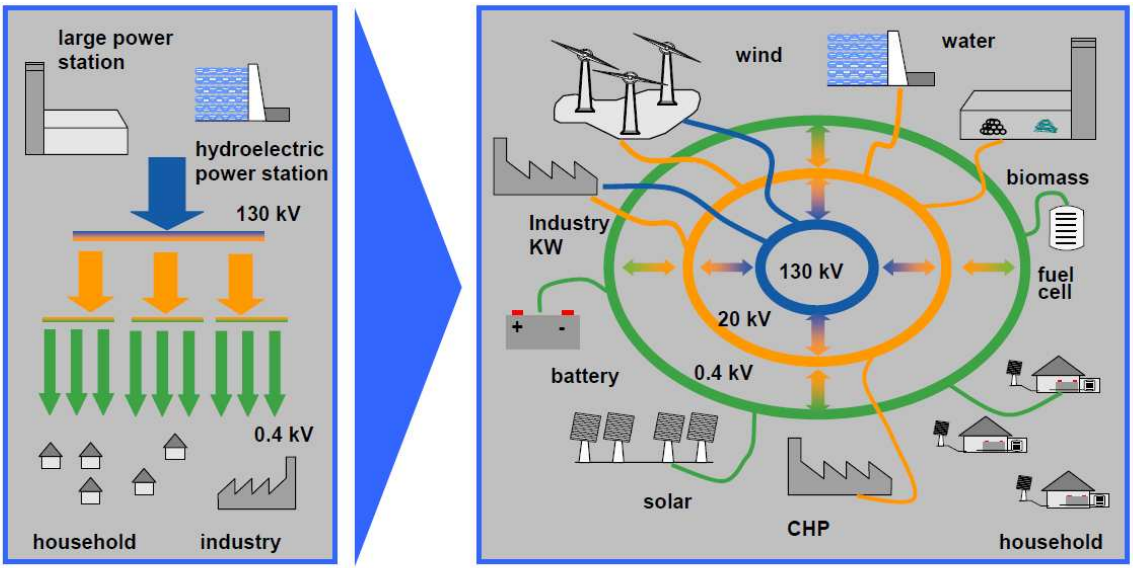


***Figure 3.3**. From a conventional grid to a smart grid system. (Brändström & Söderbom 2011)*

The ways of using the electricity will change. Instead of the traditional energy based consumption there will be power based consumption. The heat pumps are a good example of this. Normally they will require only a little energy but the grid should be prepared for the peak hours during the cold days.

When customers can monitor their own consumption hourly they can also contribute to the functioning of the electricity market by adjusting their consumption to the production. With the current version of the smart meter this is already possible technically. The customers can be guided to use the electricity so that it is beneficial to the functioning of the electricity grid, too, by shifting their loads to different times of the day so that the loads in the electricity lines would be more evenly spread in each hour of the day. Then the customers would react with their demand to the signals they get from the market. This is called demand response. The loads that could be used in demand response are first of all, heating, then house electronics and sauna, for example.

The future's distribution grid is a market place for many different kinds of energy services. It is highly automated and weather secure. The objective is to modernise the grid and put more smartness in it. Hourly-based metering on production and consumption information is available for the parties who need it. Electricity market is handled with hourly-based power information in a fully automated environment. In fault situations the grid will know the fault location and can isolate the faults automatically without disturbing the electricity distribution. Information technology is part of the electricity technique and the smart grid will continue to develop. (Europaeus 2010)

The potential of the smart grids in reducing the emissions is based on the reduction of the transmission losses, exploitation of the renewable energy sources, usage of the electric vehicles and load control by following the real-time prices. Ministry of Transport and Communications estimates that the smart meters could cut the electricity consumption during the peak hours 3 – 10 %. With smart grids the CO_2 emissions can be reduced 1 500 000 – 4 400 000 tons per year but the objective can be obtained only if the house holds and workplaces are taken into account, too. When the power of the customer increases, the customers can influence to their own consumption as the system changes more transparent. (Launonen 2010)

The EVs also play an important role in cutting down the CO_2 emissions. According to Myllymäki the EVs will certainly break through the market, the questions is only when. Their number will likely increase dramatically around 2015 – 2016 and the development will go through the plug-in hybrid vehicles (PHEV). In PHEVs there is a combustion engine that is being used when driving long distances and then there is an electric engine that is being used in the city drive. The increasing of EVs will create many challenges for the distribution network but it creates new possibilities as well. (Myllymäki 2011, interview)

The EVs are easy to take along to the demand response. Very likely when the EVs break through the demand response starts working, too. This is because the batteries of the EVs can be used as electricity storages. They will be charged when the market price of the electricity is cheap and discharged when the price is high and the electricity is needed. In Finland the slow recharge is already possible because of the engine heating infrastructure. There are plugs in many of the parking lots and there are outdoor plugs outside the buildings. The speed charging would require some new techniques and equipment. In average a car is in the move for 1 – 2 hours per day and the rest of the time it is still. Why not to recharge it when it is not in use? (Myllymäki 2011, interview)

With EVs there are also the challenges how to handle a meter point that moves. Somehow the recharging power must be directed to a certain car and not always invoice the owner of the recharging spot. For example if one goes to visit a friend and plugs his car for the recharge the charging power must be recorded to the consumption data of the car owner and not the house owner. (Karjalainen 2011, interview)

The influence of smart grids in achieving the objectives of EU 20-20-20 is important. When the customers have the chance to follow their energy consumption and see how they can make difference in it they will start to aim to more energy efficient behaviour. In this way the level of CO_2 emissions will decrease as less energy that is produced with the fossil fuels is needed. (Myllymäki 2011, interview)

3.2 Smart grids and the functionality of the electricity market

Smart grids improve the functionality of the market as with them it is possible to influence both the supply as well as the demand of energy. Smart grids enable connection of more micro production such as wind mills, solar panels and micro-CHP plants to the grid. The smart grids enable the island operation, too and the customers will have more options where to buy their energy. The customers can be more independent and they can choose when to participate to the market. It is not compulsory anymore. The DSO must have the intelligence in the grid to control all these new functions. (Karjalainen 2011, interview)

When the demand side also starts to react to the supply and the prices the electricity market that used to have almost fixed demand is beginning to look more like the idealistic market. This brings more flexibility to the market. In addition when the bottleneck in the electricity transmission can be prevented with smart grid the electricity market will benefit from that too. Then the supply of electricity is not disturbed by the insufficient capacity.

Even now the demand response exists as the two-time tariff guides people to cut down the electricity consumption during the day and to move the consumption to the night time when the electricity is cheaper. The most suitable load for demand response is heating. It is the load that one can affect the most to one's individual consumption. Also warm water supplier and fridge could be commanded automatically according to the market price of the electricity. The commands or the limits when the dropping of the loads should be done should come from the customer and not from the DSO. There could be service providers developing the systems for this. (Myllymäki 2011, interview).

New market actors are needed to offer these smart grid services and products. There can be a whole new market build around this. In this way the smart grids create new opportunities and new innovations.

From the Figure 3.4. can be seen the evolution of the smart grids according to Vattenfall's vision. The next step would be integration of small scale production which should be happening in 1 – 3 years. The realisation of demand response is further away in the future, in 7 – 10 years. Before demand response would be part of the normal everyday electricity use having low-voltage monitoring and electricity storages is necessary.

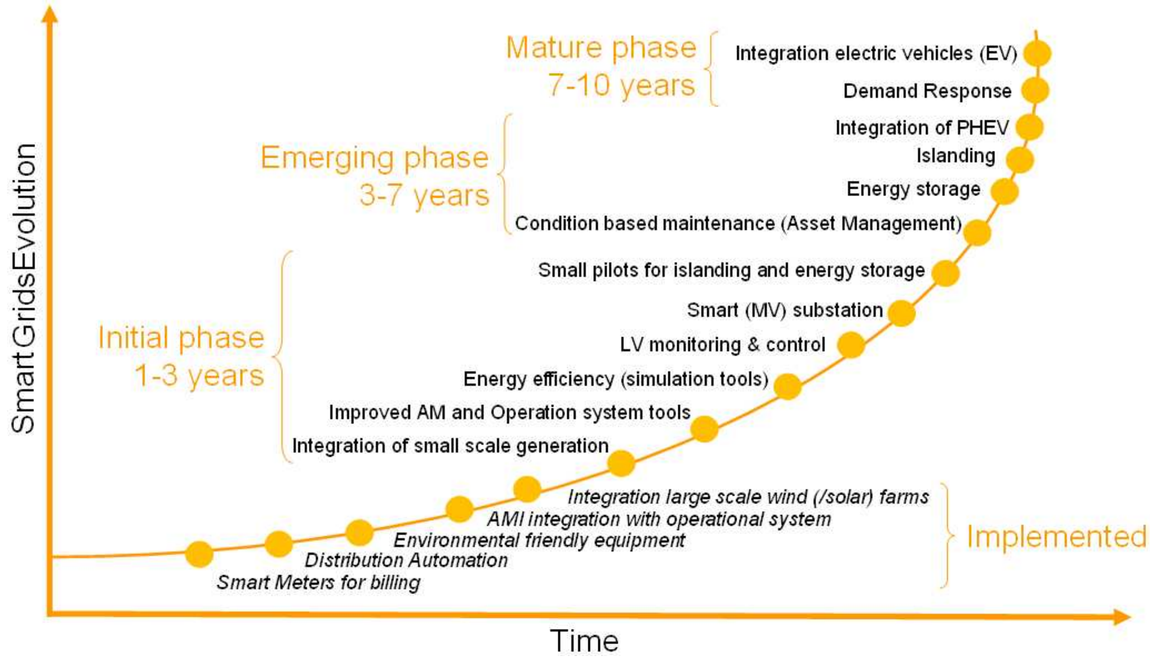


Figure 3.4. *The evolution of the smart grids (Söderström 2010).*

The generalization of smart grids will start by intelligent grid management that is characterised by the increased level of automation. Little by little the decentralised micro production will increase. Finally the electricity market will start to take advantage of the smart grids. The energy efficiency will improve. (Hänninen 2011) For the industry the drives to develop smart grids are meeting the environmental requirements and saving in the costs.

3.3 Example of a smart grid system

There are several large scale smart grid pilots on going. The smart grids will next be tested in big scale in Nordic countries in a Swedish project Smart Grid Gotland where Vattenfall takes part. Gotland is an island outside Sweden's eastern coast that holds about 60 000 inhabitants. It was chosen for this project as they already have electricity meters that can measure the values in hourly basis. There is also large share of existing wind power already and the amount will be increased to up to 1000 MW in total. There have already been many R&D projects on the island so the people of Gotland are used to participate in them. (Brändström & Söderbom 2011)

The Smart Grid Gotland is a full scale integrated demonstration and R&D project to demonstrate a future distribution system. The idea is to turn Gotland to a big test laboratory for smart grids. The existing grid will be upgraded to more modern one that allows flexible production and distribution. Customer reaction will be tested. The market actors, customers, producers and grid owners among other actors, will interact under real conditions to gain knowledge of the future electricity market. Both market and technical aspects of smart grids are covered. The driving forces for this project are solving the growing demand of electricity and meeting the demands for increasing security of supply. The assets are aging and would need reinvestments anyway. In addition the green technology and the EU's 20-20-20 targets were considered important drives for this project. With smart grids the renewable energy sources could be integrated on all levels of the electricity system. There will be charging polls for EVs and alternative heating systems such as heat pumps. The project requires strong participation from the customers' side and one of the objectives is to gather information about the higher participation from the customers and the society. With this project also the knowledge about the new roles of the actors in the electricity market and new possible products and services will be found out, as well as the new market models and future business cases. The technical information on how the integration of large amount of renewables and electric vehicles works out are important too. One of the main objectives is to see how this Gotland's smart grid model could be adopted to other markets in Europe. (Brändström & Söderbom 2011)

The pre-study was finalised at the end of May 2011 and the deployment will hopefully start in October 2011. The deployment will last 3,5 years and then the results can be seen. Though different parts of the project will be analysed along the way and there will also be parallel R&D projects that are connected to the universities during the deployment phase. The most challenging part is to get the customers to participate. They will participate if they can be shown the right benefits. The economical and environmental aspects could be a good incentive. The wind power could cover about 50 % of the load. With this project the better knowledge about the network will be gained. The project will not include EVs in a big scale even though the charging polls are included in the infrastructure. This project creates possibilities for universities and other companies to test smart grids. The existing infrastructure will be used but some new and smart features are included such as be new smart substations with new protection and control system. In addition, an energy storage, a lithium-ion battery will be brought to use. Also new concepts for solar energy will be tested. The battery is for dynamic purposes and not for the electrical market purposes though. Also the communication techniques have a very important role here as many systems need to be connected and work together. (Brändström 2011, interview)

The Gotland's electricity supply is very much different from the traditional Swedish one. Sweden has a lot of nuclear power and other kinds of base power but Gotland is dependent of wind which is quite volatile energy form. That is why Gotland project is more interesting in the European level than in the Nordic level. In Gotland about half of the energy will be produced with renewable energy sources and that is challenging for the electricity market. The optimum would be if there could be separate price models just for Gotland that would be connected to the wind production on Gotland. It is not sure yet if this kind of model can be implemented. The separate price models for Gotland are needed as if the price of the electricity came from the Spot market that is not connected to the wind production in Gotland it would not affect the customer behaviour. The objective is to get the customers' behaviour to adjust to the wind production on the island. That is one of the great challenges in the market test. Many things can be learned from Gotland in customers' behaviour vice: It will be interesting to see how customers react to different price models and how they react to direct steering of their loads and how energy efficiency thinking can change their consumption habits. The customers will be provided by a visualisation tool, steering equipment and then electricity consumption advices by mail, phone or personally. In this way also the different types of communication with the customer are evaluated. An important task is to recruit people to take part in this test. On private side the customers that consume more that 8 000 kWh per year and who have electric heating are asked to participate in the project. Then also farmers, industries and enterprises will be invited to participate, too. (Svalstedt 2011, interview)

The price models considered in Gotland could be sort of combination of different kinds of tariffs. One part could be fixed, one part for kWh:s and the last part for the peak load. Then there could be incentives or bonuses: if the customer manages to keep the consumption under some maximum load then he will get a bonus. The problem still with the power tariffs is that customers do not understand the power as they understand energy efficiency for example. Flexible time tariff from DSOs side is also under consideration. If the tariff is complex from the supplier's side then the DSO cannot have very complex tariff. Otherwise it will be too complicated for the customer. One way would be have some sort of time tariff but with more variation than just day and night. There could be day, night, afternoon and evening, for example. (Svalstedt 2011, interview)

3.4 Summary

The main drivers for the development of smart grids are customers' needs, regulation and technical development. The smart grids are needed in order to achieve the EU 20-20-20 objects. With facilitating the connection of small-scale production with the renewable energy sources the emissions of the fossil fuelled power plants can be cut down.

The change from the conventional electricity grid to smarter grid will go gradually. The heart of the smart grid is the smart meter that measures the values on hourly basis. The modern electricity meter is already quite smart. The hourly based metering allows the accurate monitoring of the consumption that then can be adjusted to the market prices of the electricity. This is called demand response. Demand response can also be driven by the capacity of the distribution network so that the load of the electrical lines is being optimised.

Demand response will probably start to be common at the same time as EVs as the electricity can be stored in the car batteries eventually. Electric heating is the most important load that can be controlled with demand response. The demand response already exists in small scale in the form of two-time tariffs where the price of the electricity is different during the night and day. This encourages people to move their consumption to night time. Around smart grids there is a market place for new products and services.

The smart grids will be tested in big scale in Gotland in Sweden where not only the new technique is tested but the market and price models too, as well as customers' reactions to these. There are other ongoing projects about smart grids in Nordics such as Bornholm in Denmark and Kalasatama in Helsinki, Finland.

4 CURRENT REGULATION AND LEGISLATION

As a member state of European Union (EU) Finland is obliged to follow the regulation and directives that EU imposes. The regulation should be implemented in the law of all the member state's law as such. The directives differ from the regulation as the national authorities can decide the means how to meet the goals the directive suggests. In each directive the date when the law should be part of the national legislation is set. The meaning of the directives is to bring different national laws into line with each other still leaving space for national regulation as well. (European Commission 2011)

Energy Market Authority's (Energiamarkkinavirasto, EMV) tasks include the supervision that the Finnish Electricity Market Act (386/1995) is followed. (ET 2011). In Sweden the role of the EMV belongs to Energimarknadsinpektionen (EI). EMV and EI have the surveillance action. They take care that the DSOs do not abuse their monopoly position. The authorities suggest improvements to the law and other requirements but they do not interfere with the market nor decide the tariffs. (Kolessar 2011, interview)

At the moment the Finnish electricity market is considered to be one of the most deregulated markets in the world. Unbundling the electricity supply business from the distribution and the letting the customer to choose the supplier are already taken far in Finland as the process has barely started in some European countries or on the other continents. The Finnish energy policy aims for functional energy markets, the security of energy supply and keeping the emissions below the limit that is set in international contracts. However, it is thought that these aims will not be realised in completely free market but some regulation is needed. The transmission and distribution need to be regulated and supervised as they are monopolistic businesses so there is no competition. In Finland Ministry of Employment and the Economy is the responsible of the regulation of the electricity market and the implementation of the EU regulation and directives. The most important directive regarding this thesis work is the Internal Market of Electricity directive. Its goals are to enhance the competition in the electricity market and to guide to the harmonisation of the European electricity markets. (ET, Lainsäädäntö ja viranomaisvalvonta 2011) In addition, the electricity distribution business is supervised by Finnish Competition Authority, Consumer Agency and Finnish Safety Agency.

4.1 Relevant legislation

The most important law of the Finnish electricity branch is Finnish Electricity Market Act (386/1995). Other laws give specifications to this law. In Sweden the structure of the electricity market legislation is similar.

4.1.1 Laws in Finland and in Sweden

The purpose of the Electricity Market Act (386/1995) is to ensure the preconditions for effectively functioning electricity market. The electricity prices should be reasonable and the electricity should be of the adequate quality. In order to reach these aims the working economic competition is ensured both in production as well as in retail of electricity. Maintaining sufficient and non-discriminatory service level in operation of electricity networks is secured. In addition to this there is Electricity market decree (65/2009) that describes the connection of the customers to the electricity grid and other DSO related matters. There are also more specific acts from the Ministry of Employment and the Economy that regulate among other things metering and unbundling. Then EMV can also enact laws that are binding.

In Sweden the system for the laws is almost equivalent. The most important law is the Electricity Act (1997:857). It provides regulations concerning power installations, trade of electricity and electrical safety. The same EU directives are valid in Sweden too and they are fitted to Swedish legislation. Then Sweden also has national electricity laws too that define the specifications about metering and reporting the metering values and accounting and such. The contents of these laws and acts are basically similar to the Finnish legislation. (EI 2011)

In addition to these, there are the European Energy Regulators: The Council of European Energy Regulators (CEER) and European Regulators' Group for Electricity and Gas (ERGEG). CEER acts like preparatory body for ERGEG. ERGEG is the European Commission’s advisory group of energy regulators. Both EI and EMV are part of these organisations. The organisations were founded to help to achieve the objective of having single electricity and gas market in EU. (European Energy Regulators 2011). Nordic energy markets have their own regulatory cooperation organisation NordREG where the members are the energy market regulators of the Nordic countries. NordREG steers the legislation towards harmonising of the Nordic electricity market. The Nordic electricity market should be integrated for the whole sale and retail market part in 2015.

In 19.9.2007 EU published the third energy market package. It includes five proposals that are Common rules for the internal market in electricity and Common rules for the internal market in natural gas, Establishing an Agency for the Cooperation of Energy Regulators (ACER), Cross-border exchanges in electricity and Access conditions to the gas transmission network. The directive concerning the common rules for the internal market in electricity 2009/72/EC sets the targets for unbundling.

In addition to these there are some general laws that are binding also in electricity business like the taxation law. The act about the excise tax of some fuels (Laki sähkön ja eräiden polttoaineiden valmisteverosta (1260/1996)) suggests that one have to pay taxes for the energy that is produced. The most important subjects to this tax are DSOs and electricity producers. The tax deals with energy content, carbon dioxide content and maintenance security tax. This law is based on the EU directive 2003/96/EC where the energy products and the minimum taxation of the fuels are being defined. The directive became valid on 1.1.2004. (Tulli – Customs 2011)

The Nordic retail market should be harmonised at least to some point in 2015. Nord Pool whole sale market is already common in Nordic countries. The harmonisation is not a goal it self. The countries are nevertheless different and not all the actions can be handled the same way in all the countries. For example the customer service quality in Nordic countries is not in as good level as in elsewhere in Europe. There is no regulation considering customer service quality but with the harmonisation the quality of the customer service will also be defined. In United Kingdom for example it is written in the law the DSO should reply to a complaint within a certain period of time. In Nordics answering is not compulsory at the moment.

4.1.2 Unbundling

The legislation aims for unbundling the distribution and supply. In the Finnish electricity business the electricity supply and the distribution are unbundled (Sähkömarkkinalaki (386/1995), § 28). Originally it was decided in EU directive 2003/54/EC that was later repealed by the directive 2009/72/EC. Unbundling rules how ownership and interaction between different market participants should be. This means that the electricity supply is free unregulated business and the customers can buy the electricity from which supplier ever they choose. Electricity distribution is still regulated by the energy market authorities as it is monopoly business. As it is not economically wise to build several parallel lines for the electricity there is only one DSO at each area. It is allowed for the DSO and the supplier to belong to the same group but the grid company has to be separated in some ways from the sales company. The DSO has to assure that all the customers are treated equally even though not all of them are buying the electricity from the same groups' sales company. The awareness of unbundling should show in the daily work within the group's different companies and the roles must be very clear. (Lindgren 2011, interview)

Customers pay for using the electricity network. To the customers the unbundling shows that in the invoice the customer receives the electricity supply and the distribution are mentioned separately. Usually if the customer has changed the supplier he receives one invoice from the supplier and another one from the DSO. In some cases it is possible for the customer to receive a combined bill, at least when the DSO belongs to the same group with the supplier company. In Finland the biggest supplier in a geographic area is called the supplier with the obligation to supply. The supplier that has the remarkable market power in the DSO's area is the retailer of the last resort (Sähkömarkkinalaki (386/1995), 21 §). This means that this supplier is obliged to deliver the electricity to the customer who does not choose the supplier by himself. In Sweden the supplier of the last resort is determined by the DSO. The grid owner can decide which ever supplier they want to. Normally this is then the supplier of the same group if there is one. (Lindgren 2011, interview)

The unbundling might be difficult for small companies to arrange. Having the customers in two separate systems both for the supplier and for the DSO part would be very costly to arrange as well as having different people in charge of the supplier and DSO tasks. They are not so much unbundled as the bigger companies are at the moment. If the rule would be too strict in this there is the risk that small players could not act on the market anymore which would lessen the competition in the market. (Svalstedt 2011, interview) That is why the companies that have less than 100 000 customers do not need to be fully unbundled in Sweden (Mattson 2011). In Finland the number for the customers in a company that can have some functions common is 50 000 and the annual amount of distributed energy during last three years should be less than 200 GWh in 400 V grid (Sähkömarkkinalaki (386/1995), § a&c 34). Unbundling means that some of the functions and processes of the supplier and DSO companies within the same group should be separated. For example the decision making should be independent in both supplier and DSO companies so that people in the network company's management cannot have leading positions in companies engaged in production or trade of electricity. The sensitive customer information that can be used to commercial purposes should not be exchanged between the DSO and the supplier. This means for example that the DSO cannot advertise the same group’s supplier in the electricity network invoice. Also if the DSO makes purchases of services within the same group the prices should be market prices so that the group does not favour the DSO. In addition, the network company management and employees should bear in mind with all their actions the non-discriminatory behaviour towards other market actors. (Mattson 2011).

At the moment in many companies the DSO and the supplier side have the same IT systems and customer services and they are operating under the same brand. In the future, it can be considered to have a completely different brand and logo for the supplier and the DSO even though they belong to the same group. (Rud 2011, interview)

All in all, the unbundling makes the market more transparent. The unbundling also helps the market functioning when looking it from the Efficient Market Hypothesis’ perspective. As in a functioning market none of the market participants should have the information that is not available for everybody. When the supply and the distribution are separated inside a group the risk of having private information that could influence the market diminishes.

4.2 Economic regulation

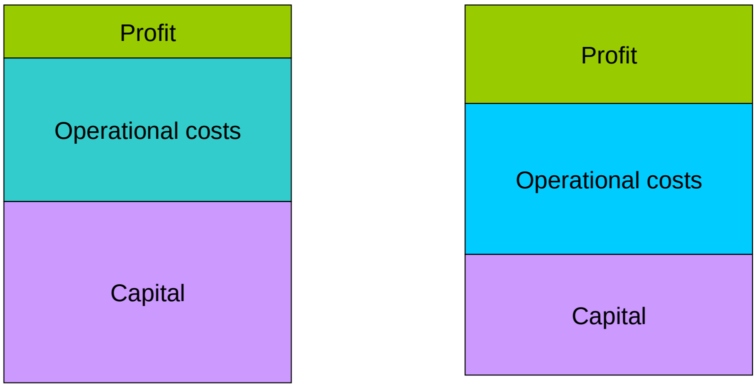
In the Finnish and Swedish regulatory models the energy market authorities set a frame of expenses for DSOs. Based on the costs of the operation and capital the DSOs are allowed to have a reasonable return. The distribution grids are in a need of big investments so that they can be updated to the smart grid era. DSOs hope that they can raise tariffs to cover the investments that have to be done soon.

4.2.1 Regulation model in Finland and in Sweden

The regulation of the DSOs means that the national regulator sets the maximum level of profit or revenues for the regulatory asset base revenue for the investments and expects DSO to maintain and to develop the electricity network (ET 2011). The regulation model in Finland is a hybrid of rate of return and revenue cap regulation. Regulation period is 4 years as in Sweden too. All network investments are included in regulated asset base based on their current replacement value at standard costs. (EURELECTRIC, pp 25 – 26)

From the year 2012 also the Swedish regulation is going to be changed to ex-ante regulation that is in use in Finland. This means that instead of checking the tariff level after it has been implied the authority approves the methodology or the frame of costs and profit before hand. Before it used to be so that the DSOs set the tariffs by themselves and at the end of the year the authorities would review them and see if they were reasonable. If the tariffs were too high according to the authorities the DSO had to pay back to the customers or lower the prices during the coming year. (Kolessar 2011, interview) In Finland it is only the methodology that is approved before hand by the regulator.

The money that the DSO invests into the grid is used for calculating the frame for the tariffs. There is often a gap between the real investment and the standard cost that is given in the regulation model. For example in Sweden for some investments it is possible to get maybe 75 - 80 % of the full investment in the tariffs because the investment is standardised. The regulators set the allowed tariffs based on the capital costs, operational costs and profit for the DSO. If the capital cost in reality is higher the DSO have to take the difference from the profit. They cannot adjust the tariffs in order to get the same amount of profit as planned. If the incentives for investments are not sufficient DSO has to use the profit share to cover the investment costs. On the other hand, if the DSO is more efficient in operational costs or does not invest capital as much as planned so that the cost frames are not fully used, they can get add the profit share. The regulation sets the frame that the DSO is allowed to earn during the four year regulatory period and the frame is based on what the regulator estimates that is going to be the capital cost, operational cost and then DSO is allowed to make profit for the last part of the set. (Richert 2011, interview). The situation in Sweden is illustrated in the Figure 4.1. If the DSO manages to save in the capital costs from the picture a) then it can increase the share of the profit as in the picture b).



a) b)

***Figure 4.1**. The cost frame for the DSO in Sweden. a) and b) present the change in the capital that can be moved to the profit.*

After four years the regulator checks if the revenues have been in line with the allowed profit level. In Sweden the requested revenue frame has to be reported to the regulator before the regulatory period begins.

4.2.2 Incentives for developing smart grids

According to EURELECTRIC smart grids need smart regulation. Adapting the networks to meet the growing electricity demand and new requirements, as well as investing in necessary replacements will require significant capital expenditure from the DSOs. The current regulation incentivises DSOs to cost-efficiency by reducing the operating expenses and thus does not encourage sufficiently in updating the grid smarter. In short of intermediate term the smart grids may seem expensive but in long term they will lead to more cost-efficient operation of the grid. Eventually it will increase the quality of service and bring many benefits to all the market actors.

There are three main shortcomings in European regulation that were identified by EURELECTRIC. Regulators are often penalising extra expenditure on smart grids as they are currently supporting cost efficiency above all and encouraging the business as usual approach. However, if the investments on smart grids were thought of the sub-optimal rates of return and the delay in recognizing the capital expenditures when setting revenue allowances are constraints on investments. In addition, the instability of the regulation and the lack of clarity in the roles and responsibilities of market players are hindering the development. There should be long term incentives for efficient delivery and the whole regulation should be more far-sighted and provide fair rate of return. (EURELECTRIC)

In the third regulation period that will start at the year 2012 the Finnish energy regulator EMV will allow 0,5 % of the turnover to be used as R&D costs. The company is obliged to show how much money it has spent on R&D and that is the maximum that the company can put through the billing. In addition to this, EMV suggests that for the sites smaller than 63 A where the DSO has installed an hourly meter and uses it for balance settlement the company could get the compensation of 5 € per site per year in 2012 – 2015.

In United Kingdom (UK) the DSOs have been encouraged to develop new technologies for future grids with innovation incentive that also lets 0,5 % to be invested in R&D. This is different model than investing in network. R&D might lead to better products and better networks in the future but the real investments are the investments that are made to the grid now to improve it. According to the EI the UK model could not be implemented in Sweden as the way of financing R&D is different than in UK. In Sweden the funds for R&D are more centrally allocated. It is tax payers' money. In UK the companies have large R&D departments that they are incentivised to use. (Kolessar 2011, interview) There are no incentives for smart grids or R&D in Sweden. The industry thinks that some sort of percentage would be good. Smaller operators are in a favour of applying incentives for well defined smart-grid projects. Smaller companies could apply this money together as a group. (Richert 2011, interview)

Developing the regulation for smart grids is difficult as the companies are different and have different kinds of networks, different kinds of customers, different geographical areas. There are special particularities in the networks so there is no single solution for all the companies that could be adapted to their particularities. Applying one single rule could increase the cost and reduce the benefits, so that is why the authorities try to focus on the output. They cannot concentrate on specific solution investments because it is not sure if this solution brings more benefits to the customers in the end. (Kolessar 2011, interview)

In the past the regulators have not been very active in developing the market. Before they made the regulation and then the other market participants had to adapt to it. Nowadays they are discussing more and asking the opinion of the industry before drawing the regulation models. The relationship between the regulators and the industry is more interactive now. (Lindgren 2011, interview). The regulator is taken more like a partner with who the DSOs can cooperate in order to find best solutions. It is not thought as a counter partner anymore. (Liiri 2011, interview). Nevertheless there is still need for the regulators both in Finland and in Sweden to make sure that everyone follows the rules.

The DSO industry legislation is interesting as the regulatory period is four years as the electoral period the parliament in Finland and Sweden too. The political drivers also influence the development of the electricity industry. Nevertheless the network investments stay in the grid for decades as the time of use for many electricity line components is up to 50 years. So in the political and regulatory decisions it should be taken into account that the investments are very long term investments even though the parliament and the regulation are set for only four years at a time. (Liuhala 2011)

4.3 Summary

As DSOs have an areal monopoly their operations have to be regulated by the authorities in order to see that the monopoly position is not used for drawing excessively large profits. In Finland the energy market authority is Energiamarkkinavirasto (EMV) and in Sweden Energimarknadinspektionen (EI). In Finland Ministry of Employment and the Economy is the responsible of the regulation of the electricity market and the implementation of the EU regulation and directives. The most important laws are in Finland Finnish Electricity Market Act (386/1995) and in Sweden Electricity Act (1997:857). The EU directives are also implied to national level eventually. The idea of unbundling the electricity distribution and transmission from the production and trading comes form the directives. Unbundling might be challenging for the small companies but all in all it adds the transparency to the market.

In Finland and in Sweden the regulation period is four years. The next period will be 2012 - 2015. In Sweden for the next four years the DSOs estimate the costs they have and from these the profit that they are allowed to have is calculated. So the regulation is done before hand with ex-ante principle. The actual prices are not regulated before hand. In Finland only the methodology is ratified before hand. At the end of the regulation period the authorities check if the revenues have been reasonable and DSOs either have to lower the prices for the next regulation period or they are allowed to increase them.

The distribution grid is in a need for new investments to enable the smart grid development. This should be taken into consideration when setting the frame for the regulation. The regulation period is only four years but the investments in the grid will stay for decades. The decisions must be of a long term kind.

5 CASES: SMALL-SCALE PRODUCTION AND DEMAND RESPONSE

In this chapter the roles of all the actors in the electricity market are being presented from the aspect of connecting small-scale production to the grid and demand response. In both cases the DSO has the centric role in enabling the functions.

Demand response is an important issue economically for the whole society. In the past huge power plants that combust fossil fuels are being constructed to cover the demand during the peak hours and these power plants are in use only a short period of time of the year. It would be more rational economically and environmentally for the whole society to make the demand adapt to the production. The distribution grid is in a key role to make this happen. (Hänninen 2011)

5.1 Actors in the market

The main actors in the Nordic electricity market at the moment are DSOs, suppliers, TSOs, producers, service providers and of course the customers. With the developing electricity market and smart grids there will be a chance for the new market players to break through the market by offering new services related to aggregating the small-scale production or demand response offerings or new information services to the customers.

There are about 90 DSOs in Finland and about 150 in Sweden. The amount changes a little year by year. According to the Electricity market act the DSOs should maintain, operate and develop its grid so that it fulfils customers' reasonable needs. They also must secure the supply of sufficiently high-standard electricity to the customers. This is called the obligation to develop the electricity system. The obligation to connect implies that DSO should provide connection to the customers who request it against reasonable compensation. The conditions and technical requirements should be non-discriminatory to those who are to be connected. (Sähkömarkkinalaki (386/1995), 9 §). The DSOs are responsible of the state of the distribution grid and the quality of the electricity that is being delivered to the customer. (EMV 2011). In the SCM the role of the DSO will be emphasized as the delivery of the valid metering values becomes more and more important in order to keep the electricity market functioning. With monopoly position come rights but also duties. That are the energy market authorities that impose the duties and secure that the DSOs follow the regulation and Electricity market act in terms of quality of supply and in tariffs. (Kolessar 2011, interview)

Transmission system operator (TSO) has the monopoly of transmitting the electricity in high-voltage. In Finland this operator is Fingrid Oyj and in Sweden Svenska

Kraftnät. Their business is also regulated and in Finland EMV is the regulator. The responsibilities of TSO are to develop the transmission grid and to manage the power balance between the consumption and production at each moment. TSO also does the balances in national level. TSO also has to improve the functioning of the electricity market. All the significant connections to the neighbour countries are in the possession of TSO. (Fingrid 2011). Today the TSO determines the available transmission capacity before market players submit their bids to Nord Pool. The available transmission capacity depends on the expected production, consumption and load flow conditions. These are not easy to predict and that is why the capacities announced to the market may be lower than the actual capacities that could be offered. (NordREG 2011)

Many electricity suppliers have their own local production units, too. In Finland there are about hundred of these. The supplier's role is to sell electricity to the customer. Customers can choose their supplier. In the SCM that will likely be implied the supplier is often the responsible of billing of the customer, both the supplier's share and for the DSO's share. The supplier receives the consumption data from the DSO once a month and bases the billing on these values. When connecting small-scale production the supplier can be the buyer too.

The customer's role will also change in the future. The customer is not only consuming electricity but now he will have the possibility of producing electricity as well. Some customers are more aware than others. Sometimes the customers do not even make difference between the DSO and the supplier. Thinking about this the supplier-centric model with the single point contact would not make much difference for the customers. In average the customers want to contact their electricity company as rarely as possible. If they sometimes need to contact the DSO or the supplier it must be easy. The security of supply will also be more important in the future and customers are more demanding when it comes to the quality of electricity. The electricity industry also expects customers to participate more to the electricity market by demand response and by producing their own electricity. On the other hand, there will always be customers who are not interested in getting this kind of information at all. They are just happy when they get electricity from the plug without outages. Maybe they save energy in other ways or they just are not interested in thinking about their consumption rate as part of their daily life. (Lautala 2011, interview)

5.2 Connecting small scale production

There are different ways to define the actual maximum kW-limit under which the production is considered to be small scale. The small-scale production is production that can be installed to an individual house or in the farm. The production is mainly used for the own purposes of the estate but occasionally it might be fed back to the grid if the production is greater than the consumption in the house.

5.2.1 Connection process

The Finnish government regulation (Valtioneuvoston asetus sähkömarkkinoista (65/2009), 1 §) states that from the customer’s request the DSO has to make an offer to the customer about connecting new generator to the grid and about the electricity transmission services. If the DSO declines the connection it has to provide the argumentation why the connecting was not possible. In the offer there must be a detailed specification of the connection requirements.

The energy authorities are supervising that DSO connects the ones who want it to the network. If the customer is not satisfied with DSO’s terms of connection regarding tariffs or technical solutions or feels that he has been treated unfairly in the connection issue he can contact the energy authorities who will solve the situation. There are quite many cases like this. (Kolessar 2011, interview)

It depends of the size of the production unit that is being connected to the grid how easy the connecting is. The process of connecting is easier for a small scale power plant than for a large scale one. From the DSO's side it has to be verified if the network needs to be strengthened or if the connection cable is enough and that the new connection does not affect the quality of electricity of the other network users. The smaller scale production is quite easily connected and the electricity meter can measure the power flow to both directions. There might be some protection related issues as selectivity of the protection. The DSO should know very precisely where there is small scale production that is connected to the low voltage network as during an outage it has to be secured that the power is not fed to the grid anymore when the workers are repairing the fault. (Myllymäki 2011, interview)

In Vattenfall Eldistribution AB the small-scale production up to 300 kW can be connected to low-voltage grid and bigger ones to medium-voltage. The production is classified in three categories according to the size: micro-scale that is up to 43,5 kW and 63 A maximum fuse size, small-scale that is 43,5 – 1500 kW and large-scale that is for bigger than 1500 kW units. The tariffs are different for different classes. (Nilsson, P.-O. 2011, interview). In Vattenfall Verkko Oy the small-scale production is regarded to be less than 50 kW. For different units the connection process is different. (Lähdeaho 2011, interview). It is important to contact the DSO in an early stage of the connection process. The information that the DSO needs is basically the type, size and location. First the customer needs to contact DSO and after receiving the data the DSO makes an initial offer to the customer. After a more detailed analysis the customer will receive an offer that he can accept or refuse. Then the connection must be paid and there must be a bank guarantee. When all this is clear the DSO confirms the order and the date when the connection will be ready. Before this only estimates of the time has been given. There also should be contact during the building process. Then the DSO advices the customer to contact licensed electrician to do the installations and the electrician can give DSO information about the protection issues and other technical matters that the customer maybe does not have sufficient knowledge of. This goes for the small-scale production if the connection exists already. The connection of the wind power is free in case there is no need to do any upgrading for the network. For example, if the connection size has to be upgraded from 25 amperes to 63 the customer has to pay the reinforcement costs. If network needs to be built the power unit owner must pay all the costs. In Vattenfall Eldistibution AB there are standard connection fees for small customers. The small-scale production connecting deals are handled by the customer service in Sweden and the bigger ones will get a personal contact from the company. For time being, there have been only a few contacts from the customers who want to have small-scale production of their own. In Vattenfall Verkko Oy the demand for small-scale production connections is even lower. It has nevertheless been thought that if the demand will increase the customer service could handle the small-scale production cases as in Sweden. (Lähdeaho 2011, interview). At the time being there is quite a small number of these kinds of connection contacts in both countries so there is no need to add the resources in handling these situations. If the number of the enquiries increases fast the DSOs have to think how to handle them and the processes should be more refined. (Nilsson, P.-O. 2011, interview). There are no clear rules how to act with small-scale production. Some DSOs have announced that they handle the small-scale production. (Englund 2011, interview). Finnish Energy Industries have published a handbook for measures for the connection of small-scale production that can be used as guidelines. In addition to this the DSOs can have guidelines of their own.

Figure 5.1. presents how the small-scale production connection should be modelled in the supplier-centric model. DSO’s role is to take care of the electricity delivery to the customer and from the customer. The DSO can use the electricity that is acquired from the customer for example to cover the distribution losses as will be discussed later. Other important task of the DSO is to collect the metering values and deliver them to supplier. Supplier receives the customer’s consumption data and based on that invoices the customer. Eventually the DSO invoices the supplier. The supplier buys the electricity from the electricity market and sells it to the customer as mostly the customer’s own production is not enough to cover the consumption.

The numbers in the picture refer to the contracts between the actors: First the supplier has to conclude an electricity sale contract with the customer concerning the electricity supply to the customer. Secondly there has to be a contract between the supplier and the DSO concerning the meter data delivery and the supplier handling the network fee billing from the customer. Lastly there is a service contract between DSO and the customer about on the linking of the place of electricity use to the distribution system (Sähkömarkkinalaki (386/1995), 25 §).

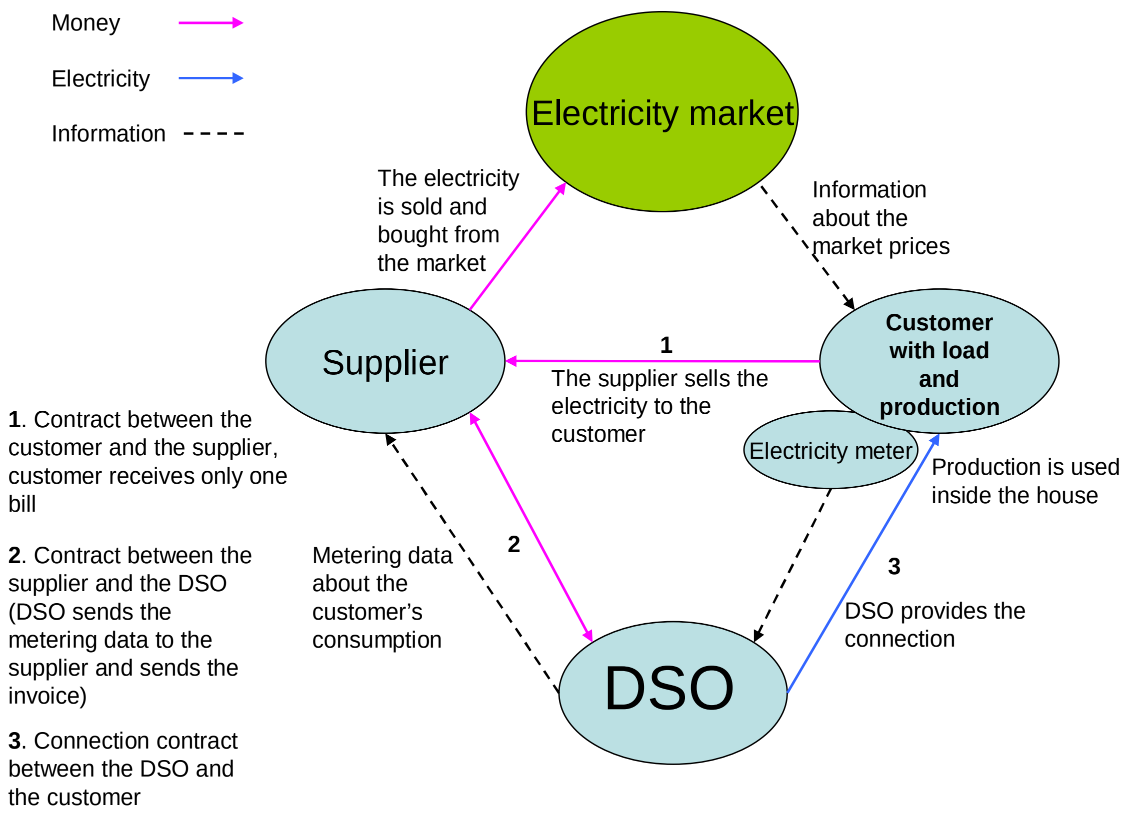


Figure 5.1. *Schematic picture of connecting small scale production.*

The situation of the renewable larger scale power plants is slightly different when comparing it to the small scale production. The power plants built for energy production are situated a bit farther away from the habitation. According to Suomen Tuulivoimayhdistys ry. (The Finnish Wind Power Association) one of the biggest problems with large scale wind power is that when the wind power company makes the contract with the DSO to reserve a certain capacity available from some area the contract is binding for two years. The wind power company has two years to complete the project or the contact will expire. There is the risk that during this time there have been other wind power companies developing their projects around the same area and if they have proceeded further they might reserve the capacity that is now available. In addition, the original wind power company may have to deal with the grid strengthening payments even though the capacity goes to another enterprise. The two years to complete a large scale wind project is not enough. For smaller ones it might be. Obtaining all the licences and other contracts takes too much time. The solution for this could be a preliminary agreement about the capacity reservation. For example if the wind power project has not proceeded in a year the contract expires. In this way there would not be so many contract reserving the capacity even though the owners are not seriously in an attempt of developing wind power. In Britain this was the problem when the long-term contracts were made but nothing was really developed in many areas. (Mikkonen 2011, interview)

The customer is obliged to give the technical details about the power plant that is about to be connected. In practice the DSOs require different kind of information about the production. Some want really detailed technical specifications and for some the basics such as the size of the power plant are enough. (Mikkonen 2011, interview)

The other problem is the obscurity of the costs of the connection. According to Electricity Market Act (Sähkömarkkinalaki (386/1995), § 14b) in case of maximum of a 2 MVA power plant the DSO is supposed charge the producer only for the costs that are directly related to the connection and not for the reinforcements that the grid needs. If the power plant that is about to be connected is bigger than 2 MVA all the costs are on the responsibility of the producer. Nevertheless among the small scale producers there has been some obscurity which costs belong to who and they have the impression that they are made to pay also the costs that actually belong to the DSO. Some DSO can justify the division of the costs with a great detail and some do not have proper calculations made. For power parks greater than 20 MW the costs of the reinforcements are reasonable. The cost per single wind mill is quite small. The problem is with the power units of 2 – 20 MW. Then the cost per single wind mill becomes very high. (Mikkonen 2011, interview)

When building the wind power there are numerous things that need to be taken under consideration. First there are the wind conditions, the shape of the land, the town planning, the road planning and the electricity grid. Very often the wind power plant cannot be built there where it would be optimal from the point of view of the grid. This causes additional costs but it cannot be influenced much. Single citizens can stop the building of the wind mills with their complaints. (Mikkonen 2011, interview) Normally people are supporting renewable production but nobody wants to have a wind mill on their back yard. The opinion often changes if the customer owns the power plant. (Hokka 2011, interview)

5.2.2 Financial aspects

Investments in wind power are made based on three criteria: the windiness of the spot, the incentives and smoothness of obtaining the permits. Finland is in the middle level in all these criteria. The on-shore applications are more complicated to get the permits. With off-shore wind mills the process is easier. The countries for more profitable wind business are Denmark and UK for the big scale production. For small scale production there are lots of opportunities in Finland. Nevertheless, in Finnish conditions the wood-based fuels and bio fuel combustion would be more efficient solution for the micro production. In addition, the solar energy is an option worth considering of. Germany is the world leader in solar business even though the solar conditions are almost equal to Finnish ones (ET 2011).

The wind power is completely depended on the feed-in tariff. Without that the wind power would not be feasible in Finland at the moment. The tariff will guarantee that the wind power producer receives certain amount of money per MWh that is not dependant of the market price of the electricity. This helps the producer to cover the costs of the investments and the capital. The law that confirms the feed-in tariffs became recently approved after long anticipation so at the moment there is a huge amount of projects to start to build larger scale wind power. The law suggests that during the three first years until the end of the year 2015 the producer will get elevated tariff that is 105,30 € / MWh and the basic tariff is 83,50 € / MWh. The elevated tariff can be obtained three years in maximum. The power production unit must be larger than 300 kW to be allowed to have these tariffs. (Hallituksen esitys 2010)

In Sweden the small-scale production is not subsidised as much as in Finland. This is curious as in Sweden there is more renewable small-scale production than in Finland. In Sweden there is a certificate system. It is a good system for large-scale renewable production. A 2 MW power production unit or larger could benefit from it but for small ones it is not beneficial. In Sweden it is the Energimyndigheten, Swedish Energy Agency that approve the certificates. If the certificate is approved the producer can get paid. When the customer buys the green certificated electricity a small share of the price goes to the producer. This system has given good results for large-scale wind power producers. It has encouraged people to start green production of electricity by them selves. In Sweden this system has existed for ten years already. (Nääs 2011, interview)

As the small-scale production is in so small volume it is difficult to find buyer for it. As a solution an obligation to buy electricity has been discussed and proposed to come to the small-scale production up to 300 kW. Most likely if there will be an obligation to buy the electricity of small-scale production it will be the suppliers' duty. (Nilsson, P.-O. 2011, interview). Because of the administrational costs for the supplier's obligation the price that would be given to the small-scale producer would be quite low. (Englund 2011, interview)

The small-scale producers can get net-benefit from DSO in Sweden as soon as they are connected. If they want to sell their electricity themselves then they have to handle it by them selves. The DSO does not handle with the supply matters. It is in the Swedish electricity law that the DSO has to pay net-benefit. The net-benefit for micro producers is 7,5 öre / kWh (about 0,8 eurocents) in Vattenfall in Sweden. The micro producers are lowering the network losses and the DSO does not need to buy this electricity from the market. As the producers are normally also consumers the micro producers keep the same tariff as before the so called fuse tariff, but for installations bigger than 63 A the energy based tariff is used. The production and the consumption are separately measured. Normally in small-scale installations the consumption is greater than the production. When the production happens to be greater the additional production is fed into the grid. In Sweden when there is a site where there is production a meter that can measure the value by hourly basis is installed. Normally for the small customers the values are measured monthly. The DSO pays the meter change. For the electricity the customer takes from the grid the normal tariffs are valid. The fixed fee part depends of the size of the fuse and there is the tariff for the energy in kWhs. The tariff structure is the same as in Finland. (Nilsson, P.-O. 2011, interview) If the production is higher than the consumption within a year the customer has to pay the costs for hourly metering and the balance settlement that are 600 SEK per year (about 60 €). If the customer is selling the energy he produces to the supplier who acts as a buyer in this situation the costs will be unreasonably high for the small-scale producer compared to the payment he will get from the electricity. The supplier needs to do the balance settlement and that adds the costs for the small-scale producer too. (Nääs 2011, interview)

There has been lots of discussion about the netting the production and consumption of the small-scale producers. This means that the consumption and production would be combined and the final combined value that usually would be some consumption is informed to the supplier for the billing. The small-scale production is stored to the gird and the producer can use this electricity when he needs it. In this way the consumption and production would not be metered separately. This would not even require a smart hourly based metering. For example, if the consumption of a household is 1000 kWh and the production is 50 kWh. Now the customer pays the normal tariff for the 1000 kWh and gets the net-benefit for the 50 kWh. In netting the customer would pay only for 950 kWh. The netting is more beneficial for the customer as then the customer does not pay the taxes. The subsidy from net-benefit is smaller than the 50 kWh saving from the normal tariff. The industry also likes this system because it is simple. (Nilsson, P.-O. 2011, interview)

The problem with this system is that the tax law does not allow netting like this. The tax must be paid for the electricity that is taken from the grid even though the electricity was produced by the customer in the first place. The electricity tax in Sweden is 25 % and the tax for consumption is 0,28 öre / kWh (Nääs 2011, interview). According to the law the taxes must be paid for all the consumption that is 1000kWh:s. Nevertheless, in Denmark it is possible to do the netting and it seems to be going well there. (Nilsson, P.-O. 2011, interview).

In Finland when the electricity is produced with wind, small-scale hydro power (maximum 1 MVA), recycled fuel, biogas or wood chips the producer can apply for subsidy for the electricity that has been produced. For wind and wood chips the amount is 0,69 eurocents / kWh, biogas and small-scale hydro power 0,42 cents / kWh and recycled fuel power 0,25 cents / kWh. (Tulli – Customs 2011)

The DSOs can charge a singe connection point with a fee of approximately 0,07 euro cents per kWh in a year of the electricity that is being fed into the grid. (Sähkömarkkina-asetus 65/2009). In Sweden the large power plant owners must pay for DSO for using the grid. If the power plant is smaller than 1500 kW the owner does not have to pay the network charge when feeding the electricity to the grid. (Nilsson, P.-O. 2011, interview)

In Finland 50 MW is the limit of being obliged to pay taxes from the energy that is produced. The smaller producers do not need to pay tax from the energy they produce. At the same time if the energy is taxable the producer has to do the balance management. Administration of the balance management becomes more costly than the benefits from selling the electricity of so small proportion. (Lähdeaho 2011, interview)

From the point of view of the customers that are interested in having small-scale production of their own it seems that the DSOs are not too willing to cooperate. For the customer it would be best if there was a clear legislation behind the connection process so that the process would be the same with all the DSOs. (Hokka 2011, interview)

For DSO the increase in the amount of small-scale production is also a challenge as the existing medium and low-voltage grid are not designed to receive distributed generation. There already are connection points that are problematic. (Söderbom 2011, interview). In addition, along with the increase of the decentralised production there will be new challenges in how to store all the data, how to validate it and finally how fast it should be transmitted. (Hänninen 2011)

5.3 Demand response

Traditionally the electricity production has been controlled to meet the consumption. In the case of a power shortage the peak power plants that use oil or gas as fuel or some other expensive and pollutant fuel were switched on. Only in the emergency cases the dropping of the loads has been put into action. In the network where there is renewable micro production the flexibility of the consumption is needed. With load control during the peak hours the consumption can be partially controlled to meet the production available at that time. In this way when both the consumption and production are flexible the best market-based economic power balance is obtained in each situation. This is feasible for both the consumer and the energy supplier. (Europaeus 2010).

5.3.1 Handling of demand response

In Norway almost all the electricity that is sold goes through the electricity market so the people are used to actively follow the prices of the electricity and are interested in demand response and the saving they can make with it. In Finland demand response is not that much known yet and in Sweden the development is lacking behind even more. To make demand response more common smart meters are needed so that the regular household customers can see their hourly consumption and the market price. The process of having an hourly metering in every household in Finland should be completed by the beginning of the year 2014. (Sallinen 2010). In Sweden there are no decisions taken regarding the hourly based metering for everybody.

In the Figure 5.2. the relations between the market actors in demand response case are presented. The electricity is physically transported from the power plant first to transmission grid, then to distribution grid and finally to the customer, the end-user. The power plant sells the electricity to the market where the supplier buys it and sells to the customer. The customer has a type of tariff that is connected to the market price of the electricity. The DSO handles the operation of the electricity meter and sends the values to the supplier. Supplier is responsible again for invoicing the customer both for its own part and for DSO's part. The customer can see the electricity prices and his own consumption from an internet application that is provided by the DSO for example. In this picture the successful information flow is a prerequisite. The numbers reflect the contracts that the market actors have in SCM.

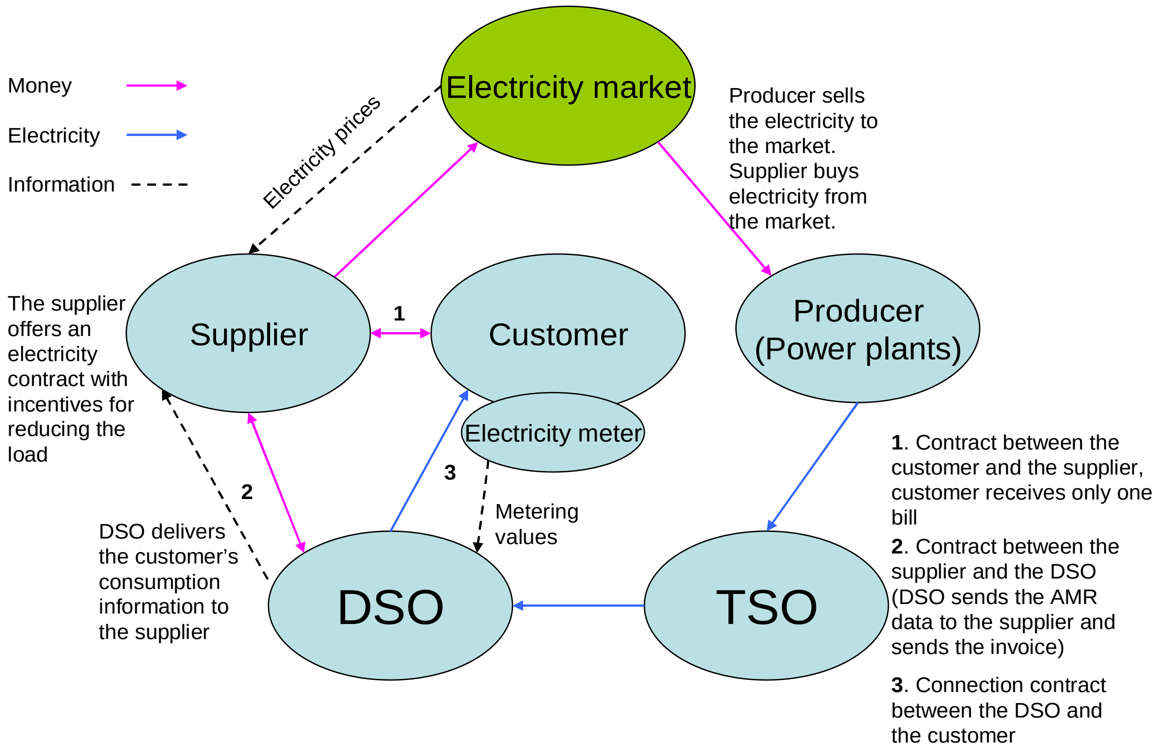


Figure 5.2. *Schematic picture of demand response in supplier centric market.*

When thinking about the ways to execute demand response the question is choosing if it should happen automatically or not. Then it also has to be so that the customer can decide about his own consumption. In addition, it would not be fair if the customers were exposed to the market prices directly because the market prices include all the environmental issues and scarcity values. It is better to execute demand response in contractual way. The contract could say that if the customer is needed to be cut off he will get compensation for that. For small house holds automatic equipment would be necessary. Many of the customers would not bother to participate manually as the savings are quite small. The most interesting part here is not the technology but rather the contractual part and who can make these contracts and install the needed equipment. (Nilsson, M. 2011, interview)

One way to guide the customer to spend electricity when there is plenty of it available and to avoid consumption when there is a shortage is to have colour codes in the display of the smart meter. For example, red represents a peak hour when the price of the electricity is high and the green colour tells that the price is low according to the price limits set by the service provider. Then the customer could switch the heating off of reduce it. In France this has been tested with success. This service could be integrated to the internet service too, but maybe the additional device is more likely. Nevertheless, automation could be a better option. Then some loads would drop automatically when the price goes above a certain limit. In the long run, it is quite unlikely that if the display would have colour codes the customer would start switching the devices on and off.

People might loose interest eventually. Heating is the most typical load to be controlled in this way but other types of loads can also be considered. In USA they tested smart washing machines that were loaded in advance and they would start washing when the price was low enough. On the other hand, all the loads cannot be controlled like food preparation for example, as people have to eat when they are hungry. Nevertheless, it will not happen that the DSO switches the devices on and off for the customer but it has to be customer's decision what devices to use and when. (Sihvola 2010, interview) The customer could set the parameters for the automated demand respond device himself. Customer can have a contract with the DSO that allows DSO to control some of customer's loads. These kinds of contracts already exist.

The loads that are the best to be controlled with demand response are heating, heating of the water. There could be a button that the customer pushes when he leaves the house and then the house automation would reduce the heating and switch off all the lights and other equipment and put the house in a sort of stand by –mode. (Willerström 2011, interview)

If the demand response reaches the normal houses with electric heating it could work with having classified the loads in the house. For example, there could be three groups of loads that are used for demand response. They could be switched off one by one according to the price of electricity. If electricity reaches some certain price all of the loads in group one would be switched off. If the price is even higher group two switches off automatically and so on. Then the groups could be formed for different seasons as winter and summer. It could work with mobile phone application: the customer receives a message that group one should be switched off now and the application asks if the customer wants to do this. It is still important that customer can decide himself if he wants to react or not. The mobile phone could be kind of remote for demand response. (Richert 2011, interview)

The demand response could also be executed by rotating shifts. For example, if there is a shortage of electricity in some area, the area could be divided into three smaller areas in case DSO is giving the signals for demand response. Then in one of these areas the loads could be cut by 10 % for an hour. Then after an hour the second area should cut down the loads for 10 % and then this continues until the shortage is solved. The DSO should then have a contract with the customers that makes this rotation possible and the customers should be informed in time before they are expected to cut the loads and they will be incentivised to do this. (Richert 2011, interview)

There has been discussion if the option for demand response should be given to everybody. The equipment is expensive and also the apartment customers cannot contribute that much to make it beneficial to participate. When constructing new buildings the energy efficiency and demand response should be taken into account. The equipment is much cheaper when installed to buildings while they are constructed rather than in old ones. It has been suggested in Sweden that the big customers who have higher electricity consumption than 8000 kWh per year would get hourly-based metering as the smaller customers' values would continue to be collected once a month. (Svalstedt 2011, interview). There are more choices to offer products to the customers when they have hourly-based metering. The customers' interest is also one thing that influences if the hourly-metering should be given to everybody. If the customer is living in a small apartment and has a very low consumption of electricity dividing this consumption per hour might seem useless. The customers with electric heating are rather the target group of the small customers. (Lindgren 2011, interview)

5.3.2 Steering the customers for demand response

In the past there have existed tariffs that encouraged to use demand response. Demand response has been discussed as it was a new thing in the market even though it has its roots in the beginning of 1970s. Though before demand response used to be more like demand side management or load control. Nowadays the customers are wanted to be more active and participate actively to the market. In Sweden there exist old special tariffs for the electrical boilers. The tariff has a low price because the DSO is allowed to disconnect them. This tariff is not so much in use today. In Sweden there has been some talk about peak shaving but nothing practical around it is going on except among considering new tariff structures. The reason is that the hourly metering is still quite rare in Sweden. On the network side the main point of interest is having lower maximum demand. This is starting to interest DSOs more and more. (Nilsson, P.-O. 2011, interview). A simple example of demand response is the dual-time tariff that is in use in Finland. During the night hours electricity is cheaper. In Sweden there are time tariffs as well but the time is set according to the seasons like winter instead of the Finnish day – night dual time tariff.

If there is big fluctuation in the hourly prices the customers could change their consumption pattern. The peak could be shifted a little without any remarkable inconvenience to the customer. The prices must fluctuate more than now at the electricity market so the customers would be willing to invest in the house equipment and pay for the new systems to invoice. It is important that the customers participate voluntarily. There must be the option to choose if to participate or not. The old fashioned load control would not work for small customers. (Söderbom 2011, interview)

One of the greatest obstacles for demand response is that there are no products available for it. At the moment it is obscure who can offer the products and the services related to this. When the supplier offers the products the customer can choose the supplier that has the most suitable products and who happens to operate in that area. The suppliers have to decide different tariff structures that will be connected to the market price of the electricity. There are some issues for the market participants to be able to give the customers the products the customers want to choose in order to get full demand response products portfolio. There is still a point for development. For DSOs this means challenges in delivering the data needed for demand response and to make the demand response technically possible to support the products the supplier offers. First the products need to be defined. DSOs have a very important role here as the whole idea of demand response is based on the hourly-based smart meter values. Depending of the resolution of the metering values there are different options and products that can be given to the customer. Also the DSO could develop products for demand response as DSO also has interests in levelling even the loads in the electricity lines by steering the customers' use of electricity. Grid side products are connected to what kind of installation it is in question. For small apartments the products will be different than from an industrial installation. (Lindgren 2011, interview)

There are examples of contracts that are done between the industrial customer and the DSO. There the DSO is allowed to cut the customer off five times per year and the customer gets a cheaper contract. Then the customer is given a short term notice with the information about the duration of the planned interruption of the distribution. Another example of a contract is of controlling the hot water boilers where the boilers could be cut off for the four most expensive hours of the 24 hours of the day. Most of the customers want to have the control on their own hands though. (Willerström 2011, interview)

If both the supplier and DSO have a dynamic tariff the risk of having contradiction between the different steering interests is possible. This might happen when the lines are highly loaded but at the same time the electricity price is low because there is lots of production available. When there is lots of wind power in the grid the customers are encouraged to consume more for example in the future by charging the batteries of the EVs or heat their hot water supplies. At the same time if the industry is working full speed there will be high load in the net. Then the contradiction is ready. The DSO wishes lower load but the market signal encourages to consume. This situation has not been seen yet but it is possible in the future. (Söderbom 2011, interview). In the Figure 5.3 the area price of electricity and the load of a medium voltage cable are presented as a function of time. During the first price peak the load is quite low. At this point the price signal from the supplier indicates to cut down the consumption but for the DSO it would be better if the customer changed some of the load of the 22 o'clock to the morning. On the other hand, in the evening the cable is heavily loaded but the electricity price sets to its minimum. The customer might get misleading signals. In this way the tariff structures of the supplier and the DSO can affect the electricity market functioning in total.

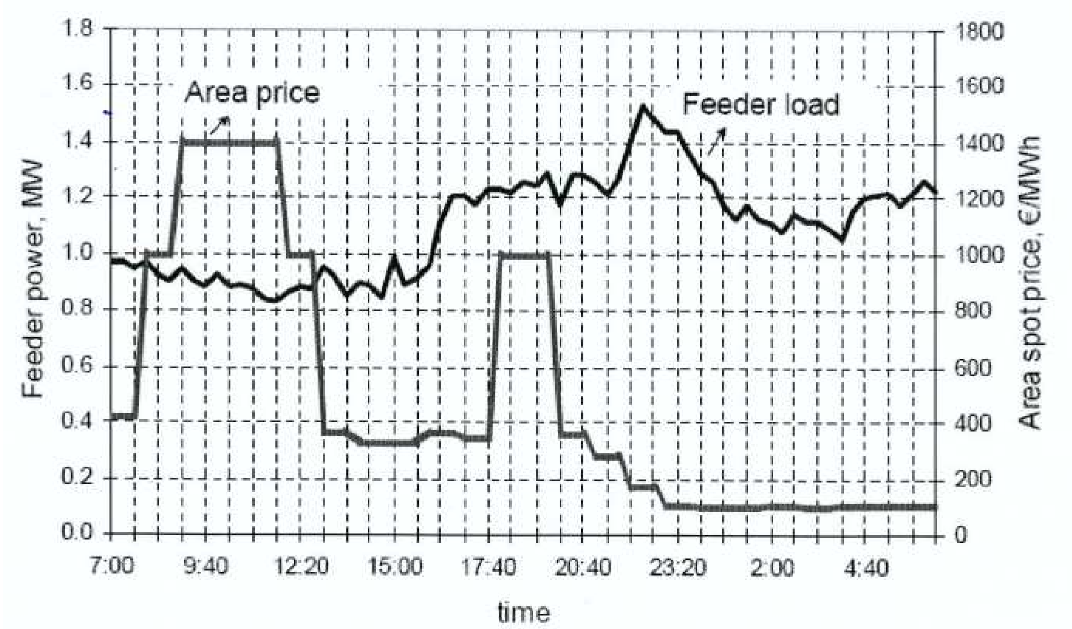


Figure 5.3*. Example of the contradictive DR needs of DSO and the electricity market (Belonogova et al. 2010).*

If the network charge was completely fixed the DSOs would lose the possibility to optimise the network use. There could be situations where the market price of electricity is low and the load on the network becomes too high because customers think it is wise to consume electricity at that moment. The network tariff should include parts that are energy or power based too. The fuse based fee could be changed somehow so that the fixed fee was low and the energy charge or the power based charge high. (Nilsson, P.-O., 2011, interview)

A way to get demand response working without developing new price model is to give customer an incentive. The customer might have a traditional fixed price agreement for one or two years but when the electricity price in the spot market gets really high the supplier sends a signal to the customer informing that now it is good to cut down the consumption. If the customer follows the advice he can get reimbursement that was mentioned in the electricity contract in the next electricity bill. This might be more likely method to steer customers in demand response rather than having contracts that follow the volatile electricity market price. (Svalstedt 2011, interview) This could even be done without hourly based metering and that is why it is considered in Sweden. The customer could be informed with mobile phone for example.

The biggest challenge in the realisation of demand response is the productisation. The supplier or some new market player should be able to develop the products and the technical service for the customers by using the data of the smart meter. Before having the right products or services for demand response the customer’s will not go for it and then on the other hand, if the customers are not interested no-one will invest in inventing the products enabling the demand response. (Hänninen 2011, interview)

There might be space for service providers in demand respond field. In Sweden demand response still seems so futuristic that this has not been thought much. First there must be the technology and a real customer need before these are going to be developed. (Lindgren 2011, interview)

5.4 Summary

The roles of the actors have to be clear for small-scale production and demand response to work. The DSOs have different kinds of protocols how to operate in the connection situation and they require different information of the production equipment in the connection situations. For larger renewable production the process of obtaining all the permits is not easy and even an individual citizen can jam the small-scale building process.

There are some incentives planned for small-scale production but they are not really working well at the moment. The feed-in tariff is mainly for larger scale production and netting the consumption and the production is not possible because of the taxation law. The lack of subsidies is hindering the small-scale production to be more common. As the demand for small-scale production connections is quite low the DSOs can handle it with low resources. If the number increases the process should be refined.

Demand response means that the consumption is reduced by the customer during the peak hours. Demand response and the benefits of it have been known in some form for decades in the industry already but now also the small customers are wanted to participate. For them the demand response should work automatically. Both the supplier and the DSO have interest in steering the customers’ consumption behaviour. The demand response can be steered by the supplier on basis of the electricity market prices or by the DSO who is aiming for optimising the grid by levelling out the high loads in the grid. Sometimes these two objectives can be in a contradiction with each other. There are many possible variations of the contracts that could encourage for demand response.

The lack of products is keeping demand response from being used to its full potential now. Hourly based metering already enables demand response.

6 BENEFITS OF THE SMART GRIDS

In the future the distribution network will work as a market place that provides to the customer a flexible connection for buying and selling electricity. The grid will work in cooperation with the customer without long interruptions in the distribution. The intelligent connection interface will enable the load and production control. (Hänninen 2011) For the DSO the smart grids offer as in a form of smart meter a way to operate the grid automatically. With remote disconnectors and circuit breakers the outage times or the outages all together can be minimized in the rural areas. Traditionally the information about the outages of the low voltage network arrives to the DSO by a call from the customer. Smart meters supervise the distribution network and can report automatically the low voltage faults they register so that the measures can be taken before the customer's call. (Europaeus 2010)

At the moment it seems that the DSO does all the development work for the smart grids and still all the market players will share the benefits. Nevertheless, the benefits for DSOs are remarkable (Hänninen 2011). Still the benefits of the smart grids are the greatest for the customer. They will get electricity with better quality. The outages will be fewer and they will be shorter. The customers will receive detailed consumption reports with outage information. In overall, the customers will get more added value to the service and more reliability to the delivery.

In addition, the smart grids increase the attractiveness of the whole electricity industry. The electricity distribution is no longer thought to be poles and cables but a rapidly developing interesting business. The society will benefit from when there will be new business opportunities for developing systems and manufacturing devices for smart grids. There will be more enterprises and then new jobs. (Myllymäki 2011, interview). Considering the two cases of small-scale production and demand response the benefits are presented below. The need for new service providers is also reflected.

6.1 Benefits of the small-scale production

The customers would participate more in the electricity market in the future, especially when they have energy production of their own. The micro producers would be highly interested in using the new services where they could see their own consumption and production and other data (Lautala 2011, interview). The customers with small-scale production will gain the feeling of being independent when producing part of their electricity by themselves. They are also saving money as they do not have to buy all the electricity from the supplier.

DSOs can use the small-scale production to cover the losses of the network and the local consumption. In the Figure 6.1. the small-scale production is presented in more detail. This picture can be compared to the Figure 5.1. In the Figure 6.1. there is a place for an aggregator who collects the small-scale production and sells it to the market. The customer has a smart meter that sends the consumption and production values to the data hub of the DSO. This hub can be maintained by some other market actor too. From the data hub the parties that need the information can get it easily. The supplier and the aggregator fetch the data from there. Customer still has the contract with the supplier as the customer's production still is not enough to cover all the consumption. The supplier could take care of the aggregator's role but the aggregator could be some new market actor as well.

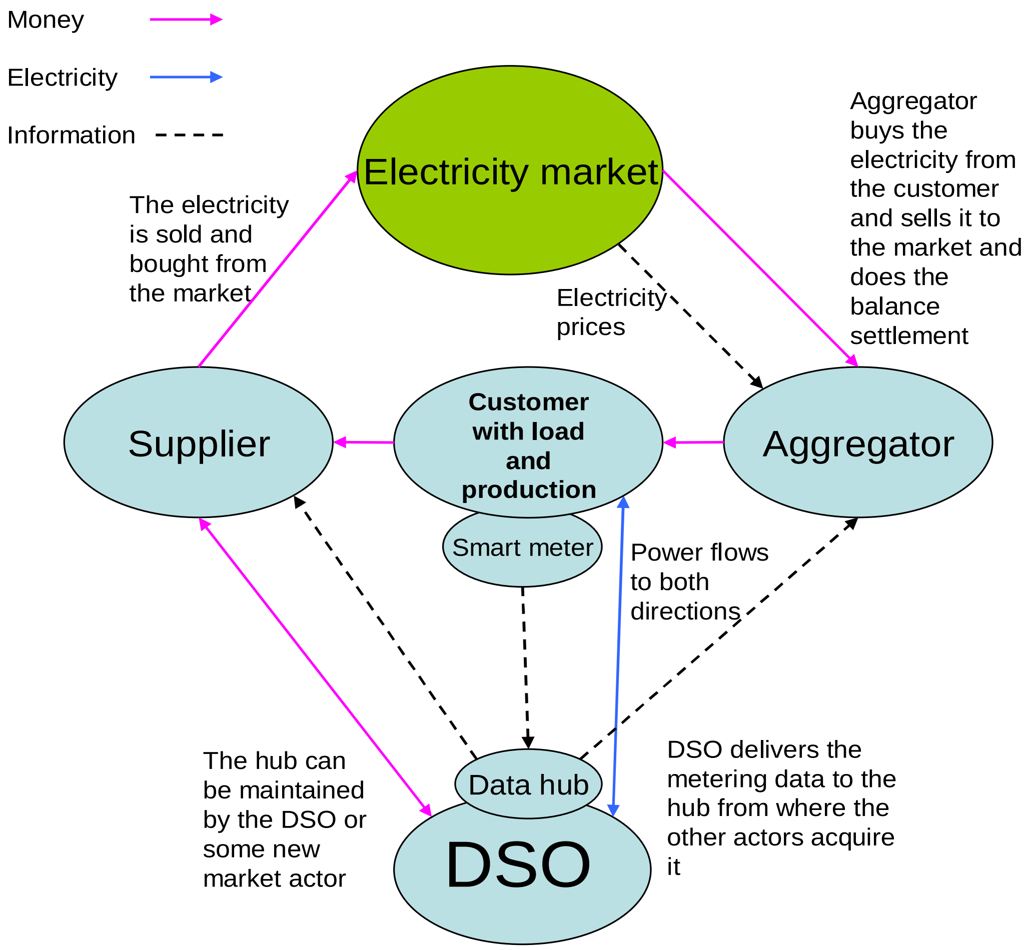


Figure 6.1. *Schematic picture of small-scale production with new market actors.*

In the future the hub where the DSO's smart meter provides the data should include just neutral information without anything extra and then all the market actors who need this information should have access to it. This raw data could then be refined and fed back to the customer's display systems so the customer can easily read the data. In SCM the monopoly part of the DSO should be limited so that it is just the basic information the DSO provides that is needed for the market to function. (Richert 2011, interview). The hub should also include the customer register about the metering point identification numbers and finding the customer should be easy from it. This kind of service is really needed. (Liiri 2011, interview)

In Germany the services for connecting small-scale production were needed so they had to develop them fast. As in Nordics there has not been such an exponential increase in the small-scale production there has not been many services developed around it yet. There is a market place for the new service providers and aggregators. Aggregator is a market actor who aggregates or collects the small-scale production and acts in the market with it handling the trading and the balance settlement issues. There is need for new low-cost solutions for customers to sell electricity to the grid. New metering concepts should be developed and this would be DSO's responsibility. (Söderbom 2011, interview).

At the moment aggregators are not needed as there are so few small-scale producers. If the number of the producers would increase a lot then there could be a need for some market party to take the aggregation business too or then it could be handled by the supplier.

It can be thought that the people do not take up wind production or any renewable production for economical reasons. They are rather fore runners and early adapters who are interested in energy business or saving the environment and have passion for energy issues. Many of them want to gain independency from their electricity company. Still the lack of incentives or any pay when feeding the left-over electricity to the grid gives the impression that the renewable production is under estimated and the administrational process to get the possible incentives or certificates is complicated. (Willerström 2011, interview)

If the small-scale producer does not see the incentives feasible he can try to sell his electricity by himself. At the moment it is quite difficult to find a supplier that is willing to buy small amounts of electricity like this. At the moment suppliers can decline as most of them do if they do not want to buy the production but recently suppliers have started to buy these small proportions too. It can be seen as a marketing opportunity. They promise that they can buy the small-scale production if the customer makes a deal with them to purchase the electricity from them. This is also good for the imago of the supplier. (Nilsson, P.-O. 2011, interview)

If the small-scale producer decides to use the electricity in the house without selling anything to the other parties he can still save money. The small-scale production affects to the energy related part and the power related part in the tariff. The customer needs less kWh:s and the maximum load decreases. (Nilsson, P.-O. 2011, interview) As many houses have recently started to have cooling devices for the summer it would be good if the small-scale production generated with solar panels for example could be used to cover that load. (Lähdeaho 2011, interview)

The benefits for the environment are the main driver for small-scale production. The electricity can be produced locally when it is not necessary to transport it for long distances. This also decreases the need for imported electricity. When the electricity is produced with renewable energy sources the need for fossil fuelled power plants decreases.

As Germany has managed to turn itself as the promised land for the renewable production with its incentives that encourage for the renewable production the manufacturing business of renewable energy equipment is also focused in the country. In this way also the society is benefiting from the development of for example solar energy systems as the own market is pulling investments to the country, too. (Myllymäki 2011, interview) This effect will increase in the future as Germany recently decided to renounce the nuclear power and replace it mainly with wind power and other renewable energy sources.

6.2 Benefits of the demand response

The peak prices tell that the markets work. It also tells that there is not enough supply in the market and more is needed. On the other hand there is some development to do in the timing the flexibility of the demand. The demand should be flexible during the actual price peak and not only when the peak is formed already. (Sallinen 2010)

The Figure 6.2. presents the demand response in the SCM with the new features. The customer has an automated system in the house that handles the demand response signals and does the disconnection of the loads automatically. It is connected to the smart meter where it can get information of the consumption and it receives the electricity market's price information. The power flow from the producer via TSO and DSO is the same as in the Figure 5.2. The supplier offers the contract to the customer that includes the demand response services. This could also be done by some new market actor. The DSO could also steer the customer to cut down the load in order to optimise the distribution network. Supplier handles the invoicing for both the supplier's and the DSO's part from the customer. Eventually DSO invoices the supplier. Again the well-functioning flow of the metering values has an essential meaning. The invoices that the supplier sends to the customer are based on the real metering values that are provided by the DSO.

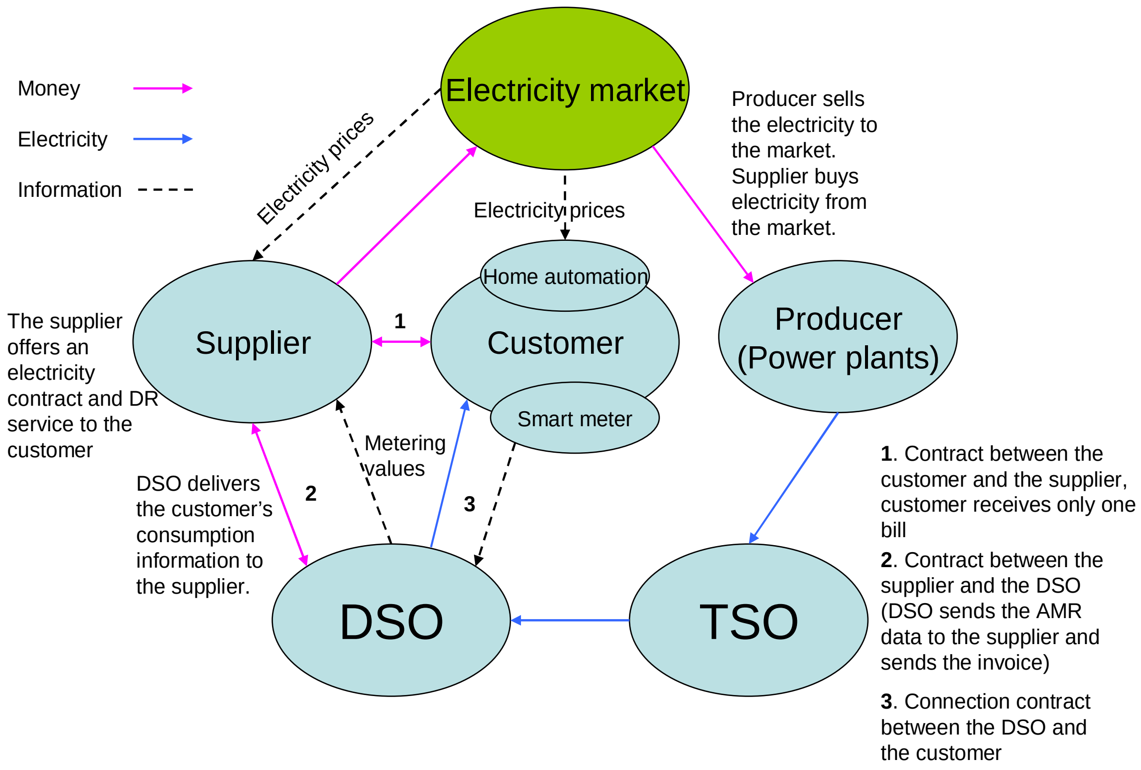


Figure 6.2. *Schematic picture of demand response with new market possibilities.*

DSO will benefit largely from the demand response. The peak shaving and moving consumption to different time of the day or week or month decreases the load in the electricity lines. In this way DSO can postpone or avoid some investments all together. The stability of the grid will also improve. In the future charging and discharging of the batteries of EVs can be used as peak shavers.

The suppliers can plan better how much electricity they have to buy from the electricity market if they can expect customers to react in a certain way. Nevertheless, then there is the risk that if the customers do not do what they promised and the forecast of the supplier are all wrong. (Hänninen 2011, interview)

Customer will be able to participate in the market better and their knowledge about the market will increase. The customers will get more possibilities to use the electricity grid. For example they can cover a share of their house heating needs with heat pumps. The intelligent homes are not far away from being reality. Electricity can already be stored in small scale which enables the demand response. In Nordic countries the electricity can be stored in hot water by nights. Then the energy is used when the market price for the electricity is high and stored again when the electricity is cheap. EVs will increase the possibilities of storing the electricity. This also increases the customers independency form the electricity companies and customers can be more satisfied. (Hänninen 2011). There have been signs of frustration from the customer's part that they can't respond to high prices. (Söderbom 2011, interview). With demand response they could participate more.

The customers that go for demand response in early stage gain the most. The ones that come along in the later stage will not gain as much. This is because the price peaks will already be flattened because of the effect of the ones that started to do the demand response earlier. All the customers will eventually benefit from demand response but for the ones that start to participate later the payback period for the investments becomes longer. (Sievi 2011, interview)

Demand response will eventually have influence to the electricity prices in the market. Very likely demand response will be executed so that the customers do not need to follow the spot prices by them selves but the DSO, the supplier or the service provider make contracts with them where so that they have the possibility to do the demand response for the customers when the price is high. For example the event of high price peaks of the winter 2009 – 2010 and the lack of them in the next winter prove that the market actors have learned. As the forecasts have to be made events like this are taken into consideration. The demand response of the customers does not turn up in the prices immediately as the prices have been decided the previous day. In the long run it will show in the prices as the suppliers have to do the forecasts how much electricity will be consumed. There will be a reaction outside the market. When the products of demand response come to use the suppliers will learn how the customers react if there will be high prices or low prices and they are aware of this or if the temperature goes low and if the customers really do the demand response when they promise. The contracts play an important part here. If the retailers have bought too much electricity from the market next time they will buy less in an equivalent situation. Then there will be less electricity in Nord Pool and the prices will be lower. This is a dynamic process. A single house hold will not directly affect the prices but dynamically he will because somebody must buy the electricity from the market that they use. In this way it is not necessary to have the house holds connected to the market directly. It's just a question of retailers understanding that they do the forecasting with lots of consumers with real time metering. And understanding how those consumers react in different areas. (Nilsson, M. 2011, interview)

As demand response cuts off the price peaks to the both directions the risk of negative prices decreases. It eases the situation for the base load producers in the network where there is lots of renewable production that increases the volatility. The producers can operate their power plants in more optimal way when the demand side acts too. With demand response there will be fewer bottlenecks in the transmission too which helps the functionality of the electricity market. (Koskelainen 2011, interview)

6.3 New market opportunities

The more detailed the information that can be offered to the customers the more it attracts people. The services that can be connected to hourly-based metering are possible. The information needs to be refined in order to put it in the form that customers can benefit from it. It could be possible that there were some new players in the market taking care of this as meter operators or data analysis. In this way the DSO enables more players to participate in the market by providing them the data that is obtained from the smart meter. This will mean new partnerships to the DSO. There could be a completely new service provider that offers a hub where the data is stored and maintained. DSO sends the metering data to this hub and the supplier and the other market players can use the data. (Karjalainen 2011, interview)

Very likely the data measurement will stay as a responsibility of the DSO as naturally the electricity meter is property of DSO. The new services that use the data of the meter could be more detailed consumption information and a comparison of the consumption to a consumption of certain group of people. These groups could be segmented e.g. according to the type of heating. Also the consumption data from the previous year could be interesting as well as the outage data and the alarm services. The customer could set the alarm to work when the level of consumption surpasses certain percentage level or kWh level or the alarm could inform the customer when the electricity price in the market is above some high level. The customer could get the notification of this to the mobile phone and could reduce the consumption by switching off electric devices and heating also remotely via mobile phone. Also providing a monthly report about the consumption data summary could be an interesting service to offer. An SMS could be sent to the customer that the report can be found from the e-mail now. (Lautala 2011, interview)

Demand response could also offer space in the market for the new players. It is still unclear who informs the customer that now he could cut down the consumption or recharge the battery of the EV and via which media this notification should be given. There could be external displays that are connected to the smart meter. With the current version of electricity meter this kind of connection of a display is already possible. In this separate display in addition to the consumption rate there could be the electricity market price presented as a function of time. (Lautala 2011, interview)

In case of Vattenfall Verkko Oy the electricity meter has a Mbus connection port available already. Some standardisation for the display is needed though. The services via this device should be developed constantly to keep the customers interested. One option is to provide scenario models: For example based on the consumption and the temperatures of the previous years the consumption curve prospect of 12 months is shown to the customer. Then if the objective is to cut down the electricity consumption with 5 % the new consumption curve is shown with the means to be taken in order to achieve the objective. (Sihvola 2010, interview)

Before the services will be offered the provider has to be sure that there is a need for those. One should ask the customers if they are interested and if they are willing to pay any extra fee for the services. The services should not be pushed forward to everybody and to make all the customers pay for them. People in the electricity industry often think that the electricity business is so interesting to everybody even though customers are mostly interested about minimising the electricity bill. The extra services-hourly based metering enables do not interest all the customers and thus are not necessary for everybody. (Englund 2011, interview)

6.4 Summary

The smart grids offer benefits to all the market participants and the environment. With small-scale production a larger part of the electricity will be produced with renewable energy sources which decreases the need of fossil fuels and the imported energy. Customers can be more independent from their electricity company as they produce part of their own electricity. This increases the customer satisfaction as they can participate more actively to the market and it also offers a way for them to save money.

With demand response the DSO can optimise the network. When the peak loads are lower in the network the DSO can avoid or postpone some investments of making the grid stronger. The supplier can make better forecasts of the electricity they buy from the market. This decreases the risk of their operation.

The smart girds offer the possibility for the new market actors to enter the market. Many services such as data hubs and aggregation services are needed when the smart grids are fully integrated to the electricity grid. Providing the equipment itself for demand response and the energy efficiency monitoring is a good market opportunity. Nevertheless when developing the sophisticated solutions for the smart grids it has to be thought what the customers really want.

Eventually the whole society will benefit from the well-functioning market and the development of the smart grids. If the Nordic countries take the leading role in the development the area will attract new enterprises and in that way there will be more jobs and tax income for the states.

7 RESULTS

As already mentioned before the smart grids can improve the functionality of the electricity market. In the Figure 3.1. the regulation and legislation were mentioned as one of the drivers for smart grids. In this chapter the thoughts how the regulation can incentivise to develop smart grids are presented. In addition the opinions of how to remove the obstacles from smart grids way are analysed.

The opinions of the interviewees were sometimes in contradiction and sometimes in accordance with each other. In this chapter the opinions of the specialists about the functionality of the electricity market, connecting small-scale production and demand response are collected.

7.1 Findings of the interviews

First the opinions about the functionality of the Nordic electricity market are reflected, and then the issues and incentives related to small-scale production and then demand response are discussed. The results are shown in brief in table form and then analysed in more detail below. Lastly there is some reflection about the role of the DSO in participating to develop the new services that smart grids enable.

7.1.1 Opinions about the functionality of the electricity market

Mostly the opinions were supporting the view that the electricity market works. Technically it seems to be working but the lack of customers' understanding decreases the points a little. The interviewees had varied opinions how to define the working of the market. Some had economical approach and others an approach from the customers' point of view. The results are shown in brief in the Table 7.1.

Table 7.1. *Factors that describe the functioning or the mal-functioning of the electricity market.*

Functioning market	**Mal-functioning market**
Enough competition	Too little competition
Activity in changing the supplier	Customer's do not understand the market
Majority of the electricity exchanged in Nord Pool	The processes should be more refined in the regulated market, too many exceptions
The price in the market is set according to demand and supply	
High and accurate meter reading values	

One of the main points in defining the functionality of the market was the competition. The number of the participants in the electricity market was adequate to most of the interviewees. On the other hand it can be questioned what is a sufficient number of the participants in the market to make it functioning. According to the chapter 2 the definition is that no single supplier can affect the price of the electricity by its actions.

The electricity market in Finland is quite concentrated. The four largest energy producers produce 60 % of all the electricity and they possess 80 % of the most feasible energy sources such as nuclear and hydro power. There should be more competition in these fields. The big companies can influence the market price which is against the principle of functioning market. (Koskelainen 2011, interview). In addition, the electricity market is supposed to be open for everybody. Now it is open to the buyers but it should be open for the sellers, too. It is quite tricky to enter the market when selling electricity. (Sihvola 2010, interview). In the chapter 5 the problems of connecting small scale production were presented.

One proof that electricity market works well is that most of the electricity in Nordic level is exchanged in Nord Pool which gives the market high liquidity. It can also be seen that high demand or lack of generation makes the electricity market price increase. That is a sign of having functioning market. (Söderbom 2011, interview). In Nordic level 75 % of the electricity is exchanged in Nord Pool. In Sweden the percentage is 90, 57 in Finland and 65 in Norway. The reason for the high percentage in Sweden was that the energy companies wanted to show outside that the electricity market functions. In order to do that they decided to push as much electricity through the market as possible instead of the OTC market. Before the decision 60 % of the Swedish electricity was exchanged in Nord Pool. Before the customers thought that the companies are not putting the real price for the electricity but making profit with the high prices. By adding the volume in the market the industry wanted to give transparency to the price forming and improve the imago of the business. After this the big companies sell the electricity to the market and the supplier division of the same company buys the electricity from the market with the market price instead of buying it straight from the producer with cheaper price. The production is not unbundled from the supplying business by any directive but this was done for the imago reasons in order to prove to the customer that the electricity market works as it defines the price for the electricity. (Richert 2011, interview)

When adding the number of small-scale production there would be more actors in the market even though the customer would probably not be selling their micro production straight to the market. The supplier or some other market actor could do this. One of the principles of functioning market is that the joining to the market is voluntary. Because electricity is a common utility that people need to purchase in order to live up to the standards of modern society the customer could have not been able to choose whether to participate to the electricity market or not. Along with the small-scale production of their own they gain more independency from their DSO and the supplier.

There is a risk that the SCM is harmful to the market because then the participation to the market for some small actors will be more difficult. The level of administration for the suppliers will increase and it might be too heavy for small suppliers to handle. There would be pressure to put the costs of added administrative costs to the tariffs. (Nieminen 2011, interview). For example handling the situations of changing the supplier might be too much work for a small supply company when the number of these situations is expected to rise in the future. At the moment even finding a customer in the system requires lot of manual work and that makes the cost of a single change very high. The supplier companies should increase the level of automation (Liiri 2011, interview). The small suppliers could have to sell their operations to some other party or they have to merge with another small supplier. At the moment there are about 500 suppliers in the Nordic market so if the number is reduced to 200 it still is not a big problem to the functioning of the market. There might be some suppliers that do not want to operate in the Nordic market anymore. They want to concentrate on their own area. Within their area most of their customers are very close where the company is situated. For example in Sollentuna, Sweden the company has maybe 90 % of the customers in Sollentuna and no customers outside. Almost no other companies have managed to penetrate the market there. The SCM model can also be problematic in case if some customers choose a cheap and small supplier that suddenly goes out of business. What happens to the DSOs money then if the supplier was supposed to handle all the billing? This increases the risk for DSOs too when letting somebody else do the billing for them. (Richert 2011, interview). If in the future the market is difficult for small companies to penetrate is it bad for the functioning of the market if the smallest companies that have problems in handling all the administration are left out?

The whole idea of SCM is a bit contradictory with developing the smart grids and especially the demand response. It is the DSO who has the major interest to move the loads to different time and in SCM the DSO would not have the direct connection to the customer. Supplier or even the third market actor who takes care of the demand response do not necessary have the interests to do the same as DSO. Then the DSO will lose the incentive to act in the market where the price volatility is increasing. It would be complicated if the DSO would have to tell the entity between DSO and the customer to make the customer to cut down the consumption for a while. The SCM model has other advantages as being simple to the customer but it puts too much burden on the regulators which they should not have. Smart grid idea is having the actors being active in the market and the SCM limits the innovations by too strict role division. (Nilsson, M. 2011, interview)

One of the opinions that suggest that electricity market obviously does not work is based on the fact that as the customers do not understand the working of the electricity market and the separate roles of the supplier and the DSO. When the customers whom the electricity market really is developed for do not understand the market the market cannot work. (Svalstedt 2011, interview). The customers' activity in changing the supplier can be seen as an indicator of the functionality level. The number has been about

8 % in Finland during the past two years and this percentage was considered to be high enough (Värilä 2011, interview). The customers are active in Sweden too. The possibility of choosing the supplier is important for the customer and the possibility to choose in what way the electricity is produced makes the customers feel that they can participate and influence in the electricity market. The customers need the alternatives such as buying green electricity. They are willing to pay more for environmentally friendly produced electricity. (Hokka 2011, interview). When the customers' awareness of the market and their own possibilities to influence their electricity bill increases the demand response also becomes possible. The problem is how to educate people to understand the electricity market better. Electricity is not that interesting to the customers as industry often thinks. (Rud 2011, interview)

The model of having more price areas has also encountered some criticism. With more areas there will be more administration which adds the costs and in addition, there has to be more balance settlements done. The risks will be higher for the suppliers and the hedging possibilities are limited. This might lead to reduction in the number of the suppliers in some areas which means that there would be less competition which is harmful to the functioning of the electricity market. The role of the large supplier emphasises still and then they can affect the market prices. Eventually electricity companies might suffer from reduced willingness to invest due to lower returns. In addition, the risk of the possibility of the negative prices increases. (Thorstensson, 2011). The suppliers will have to handle the risk. If there are about hundred electricity suppliers in the whole country now it is not sure if all of them are going to operate in all of the areas. In Sweden majority of the customers are in the two southern areas. The density of the population in the two northern areas is lower than in the south. (Richert 2011, interview). The further the market goes from counter trading the more risk there is on the supplier. In the counter trade the risk is on the tariff payers. When going to the market splitting the risk is removed from the tariff payers to the suppliers. The risk for the suppliers is geographical. In the north there are the large hydro reservoirs and the hydro power is easy to control and predict. In the south, on the other hand, there are the wind power parks and other forms of electricity production that are not so easily predictable. In this way it is easier to predict the prices in north than in the south. In south there are more customers but the risks for operation are higher. The risk might realise when the supplier operates in different areas: For example when the supplier buys a lot of electricity in the north and wants to sell in the south. Then it might happen that the demand in the south is larger that the amount of electricity that was bought from the north and to cover the need the supplier has to buy the expensive electricity from the southern market. When living in some area where some good is produced it is logical that the price of the good is cheaper there. Then regulation and legislation should be developed to get the hedging possibilities for this. TSO could sell the hedging instruments and then there could be liquid hedging market too. (Nilsson, M. 2011, interview)

These price areas will make the electricity market even more complicated for the customers to understand. It seems unfair for them to pay different amount of money according to the place they live within the same country. (Englund 2011, interview). On the other hand, it could be discussed if it is fair that the Danish pay more than the Swedish only 20 km away. Sweden is a large country. If comparing the distance of the points that are the most southern and the most northern the distance is the same as between Hamburg and Milan. Demanding that Sweden should stick with only one price area would be equivalent in demanding that the people in Hamburg should pay as much of their electricity as people in Milan if the distance and infrastructure should not matter. The price of the service should be set according to the underlying infrastructure. If there are bottlenecks they should be shown in the prices. (Nilsson, M. 2011, interview). In addition, the whole system where the price areas follow the national borders could be reviewed. The new lines could be set to their natural places, according to the infrastructure instead. Having the northern parts of Finland, Sweden and Norway and then a different price for the southern parts of the countries plus Denmark could be one option. Like this the liquidity could be improved. (Koskelainen 2011, interview)

Market splitting has also been seen to be in contradiction with the forming of the common Nordic electricity market. The prices will be different than when counter trading but the price movements are to the same direction. It can also be asked if the European market needs only one price. The price differences in different areas just take the transportation cost into account. There is the global price but the prices vary locally. Having only one price isolates the customers and the suppliers from the issue where they are consuming. (Nilsson, M. 2011, interview). The areal division also gives the correct signal that as electricity has more demand in the south, the production should also start to concentrate to the south. Price areas help to make price forming in the market more perfect. At the moment almost half of the energy production is in the two northern areas even though the majority of the people can be found from the south. Before there used to be a quite good balance but then some nuclear power plants were closed down and now the production is unequally spread across the country. Because of this transporting electricity from Northern Sweden to the customers costs and that is why electricity is more expensive in the south of Sweden than in the north. (Richert 2011, interview)

Finland remains with one price area for now and there does not seem to be acute reason to split Finland in two parts. There have not been as serious bottlenecks as in Sweden. (Richert 2011, interview) On the other hand, according to M. Nilsson there starts to be pressure to split Finland in two price areas as well. Northern Finland would belong to the same price area as Northern Sweden. Finland has been exporting less and less electricity over the border to Sweden. This indicates that there might be bottleneck problems in the inner land that are being pushed to the borders. The counter trade is not done when it should be. (Nilsson, M. 2011, interview)

When people understand the reason of the price areas they might change their opinion about being against building the new transmission lines. There will be the public pressure to build a better infrastructure. Eventually for the customers the market splitting is cheaper option than counter trading as then they do not have to pay for the export and import. (Nilsson, M. 2011, interview). When the customers in Sweden see their electricity bill with the new areal prices starting from the November 2011 there will surely be some reactions.

7.1.2 Small-scale production and incentives

There are no major technical problems that keep small-scale production from getting more common in the Nordic countries. The few technical problems might be that the equipment that is about to be connected does not fulfil the requirements or if some area has very much of small-scale production then it might be problematic for the network.

In the Table 7.2. the advantages and the obstacles of small-scale production are presented. In this case also the opinions were varied.

Table 7.2. *Advantages of small scale production and reasons why there is not more of it.*

Advantages of small-scale production	**Obstacles for small-scale production**
Way to achieve 20-20-20 target	Difficulties in the connection process
No need for new central power plants	Difficulties in finding the buyer
Increases the independency of the customers	Customers becoming too independent and DSO becomes obsolete
New business opportunities for aggregators	More fluctuation to the market price
	Protection of the grid (more trouble for the DSO)
	Expensive equipment
	Lack of incentives, not economically profitable

Mainly the advantages of the small-scale production are related to the environment. Small-scale production also gives a chance for the new market actors to enter the market. This is good when thinking the functionality of the market.

For the DSO the increase in the amount of small-scale production creates new situations. There can be some areas where the production with renewables starts to increase fast. One of these concentrations can be seen in Lappeenranta, in Finland. There the DSO has to deal with the increasing costs because of connecting the small-scale production. Is it fair that some DSOs who happen to have an area where the customers are interested in building lots of distributed generation should pay all the costs? Should the DSO get some compensation for this in form of increasing the distribution prices? At the moment this is not a big issue but in the future if there will be a lot more small-scale production these questions have to be thought about. (Nilsson, M. 2011, interview)

As the energy from the renewables is not always available for example then when the wind is not blowing, the electricity market price will be very high. In the future the volatility of the electricity prices will be much greater than nowadays because of this.

When there is lots of wind energy available the prices might go even negative. These price peaks will surely attract some players to the market who want to earn money with them but the competition is possible only if they are allowed to compete on equal terms. Nordic countries where there is lots of hydro power will not suffer from this as badly as England, Netherlands and Germany who rely on gas. For large industry customers hedging against these price peaks will be difficult. (Nilsson, M. 2011, interview)

In order to make small-scale production more common the incentives can be considered to smoothen the way. Many incentive systems have been thought but none of them seems to be working now. In the table 7.3. the advantages and the disadvantages of some incentive methods are presented and analysed below.

Table 7.3. *Pros and cons of the different incentive methods.*

Incentive	**Advantage**	**Disadvantage**
Feed-in tariff	Fast way to kick it off	Not good in the long run Twists the market Too heavy administration Decision of the law is too slow
Netting	Simple The most beneficial way for the customer	Taxation law makes it impossible The electricity does not go through the market Suppliers cannot get their own production sold
Obligation to buy	Solves the problem of finding the buyer	Not a market based solution
Certificate	Environmental	Not for the smaller producers
Subsidy to buy the equipment	Encourages customers to take the opportunity Has worked with alternative heating systems	

The feed-in tariff has recently been taken into use in Finland. During the first three years until the end of the year 2015 the producer will get elevated tariff that is 105,30 € / MWh and the basic tariff is 83,50 € / MWh. The elevated tariff can be obtained three years in maximum. The bottom limit for obtaining these tariffs is 300 kW. (Hallituksen esitys 2010). At the moment for feed-in tariffs to be beneficial the producer should own a whole wind park (Lähdeaho 2011, interview). The level of the tariffs is good for windy spots. It steers to build the production to the coasts. It is a good way to get processes started but it is not enough to cover the costs of the production that is build to inner land or the off-shore wind power plants. The elevated tariff encourages building the power plants fast but getting all the permits is a low process and if the elevated tariff is stopped in 2015 there is not much time to benefit from it. The limit should be lower so smaller producers could benefit from these tariffs too. (Mikkonen 2011, interview)

Almost unanimously the interviewees of the industry were supporting the netting when it comes to the ways of promoting the small-scale production. It is the most simple and most cost efficient way. For the customer it provides more money than any planned feed-in tariff or certificate system. In the electricity bill there could just be listed how many kWh:s the customer has consumed and how much he fed into the grid. Then he would pay the difference of these. It would only be the net energy that is announced to the supplier and for the other market actors. Actually the hourly-based metering would not be necessary when doing the netting in monthly basis but the values could still be measured only monthly and the administration of this system would be light. (Englund 2011, interview). On the other hand, hourly-based metering offers more accurate way to count the difference between the consumption and the production. The price of the electricity is very different during the night and the day. In this way monthly metering would not be reasonable. Netting by hour is seen more fair for some parties. (Mikkonen 2011, interview)

If the netting was introduced then suppliers could not sell as much electricity to the customer as before. Nevertheless, suppliers' attitude towards netting has not been negative. The simplicity of the system interests the industry and it is better option than obligation to buy the electricity. (Nilsson, P.-O. 2011, interview). Perhaps in the future they could have higher tariff for the small-scale producers who still mostly are consuming. (Englund 2011, interview) The suppliers would still be interested in selling some amount of electricity at least. Netting would not put them out of the business as the proportions that are fed back to the grid are still so small. This could even be a possibility for them to show good will that they are willing to take the small-scale producer as their customer without problem even though they produce some of their own electricity. (Richert 2011, interview)

Nevertheless, netting will not be possible in the near future because of the tax law. Netting is in contradiction with the EU law and national legislation in Finland and in Sweden. There have been investigations if this law could be changed but it is not likely going to happen any time soon. The state would lose income if the law was changed. The industry and especially the DSOs favour this method as it is not their money in the stake and it would be very simple for them to handle. (Kolessar 2011, interview). On the other hand, the tax authorities would gain more money in the form of VAT that they would get from all the equipment that is sold for the small-scale production. In the long run the netting would be best for them too. By allowing netting the small-scale production business would have such a boast that the tax from the equipment would surely cover the electricity tax from the very small proportion of electricity that the small-scale producers occasionally store to the grid. For the customer this is also the simplest way and the customers appreciate that they can produce their electricity by them selves. In this way it is emotional and technically most simple solution at the same time. (Richert 2011, interview)

Some people can see that netting distorts the electricity market. Then the people who have production of their own are in a better position than those who do not have the possibility to produce electricity. On the other hand, they produce the electricity by them selves and they have a right for it. Allowing netting could be a way to support small-scale production. (Nilsson, P.-O. 2011, interview). If the energy system should be greener and politicians would promote this, then this netting could be a good incentive for green production. (Nääs 2011, interview). There should be a limit in MW:s for whom the netting is allowed. The netting system should be only for the small household producers. (Englund 2011, interview)

The authorities’ opinion is that nothing stops small-scale producer from selling their energy if they find a buyer for it and when the small-scale production is used in the house, beyond the electricity meter. This still decreases the amount of energy that has to be bought from the grid and in that way the customer can save money. The problem is made bigger than it really is. The netting is not the solution if the goal is to increase the amount small-scale production. The feed-in tariffs would work better. Feed-in tariffs would increase the problems in administration and would require more investments to the grid from the DSOs. It has to be thought if that is what is really wanted. This is rather political question and that is why the energy regulators will not take part in this. (Kolessar 2011, interview)

When the production of electricity in some energy forms is incentivised it means that some other energy sources and other market actors that could have been in the market by their own merits are pushed out of the market. Eventually renewables like wind power have to survive in the market by their own merits, too. Some opinions suggest that it is already a competitive energy form even without the subsidy system. If the wind power still needs a subsidy system in 20 – 35 years it could be considered again if that kind of power form is wanted or should the system be regulated. Regulation is always more expensive in total than working market. That is why the electricity market was deregulated in the first place. (Nilsson, M. 2011, interview)

The Swedish certificate system could be reached to the small-scale producers too. In this way the structure of the certificate system and the administration do not have to be changed. The certificate is less than the Finnish feed-in tariff. Still, it is more beneficial to use the electricity for the own purposes than to sell it to the market. When using the electricity for the own purposes the producer avoids purchasing the electricity from the supplier and also can avoid the taxes. From solar panels the installation allowance can be obtained. This allowance comes from the government and not from the DSO. (Nilsson, P.-O. 2011, interview)

It has to be thought what the objective is. If it is just to push as much renewable power to the market the supplier's obligation to buy would then be an option to consider. The system like this would nevertheless be heavy to administrate compared to the small aggregated volume of the small-scale production. (Nääs 2011, interview) The opinion is that it would be better to let DSO handle the small-scale production as they have the losses in the net. (Englund 2011, interview) Supplier's obligation to buy electricity would also make the market more complicated. Then the risk is moved from the producer to the supplier. They will have difficulties in hedging against the risk. It is difficult to predict where it winds and how much they then should be paying according to the obligation. (Nilsson, M. 2011, interview)

The situation might get chaotic if all the smallest producers are let to connect where ever and they are highly incentivised which seems to be the situation in Germany. On the other hand, it is not good if connecting small-scale production and benefiting from it is made excessively complicated and expensive as is the situation in Finland. (Nieminen 2011, interview)

7.1.3 Demand response and the challenges in it

Demand response is seen as very good new thing even though its roots are in the 1970s. In the Table 7.4. the advantages and the sceptical thoughts about demand response are shown.

Table 7.4. *Advantages and challenges of demand response.*

Advantages of DR	**Challenges in DR**
Optimisation of the network operation = Peak shaving	Difficult to get the customers understand
Equalises the price fluctuation in the market (that renewables add)	People are not ready to cut down their consumption or follow when somebody tells them to.
Environmental (no need to start peak power plants, reaching the 20-20-20 objective)	Risk that the customer does not do what he promised
Way for the customers to save money	Lack of products Deciding good price tariffs
	In Sweden installing the smart meter to every house is thought to be expensive
	The wanted influence to market can be obtained with only the biggest customers

The hourly-based meter reading enables the demand response. In Sweden demand response seems to be further away as for the majority of the customers the electricity meter is read only once a month. Sweden is nevertheless going more towards Finnish model. The lack of interest in hourly-based metering is due to the fact that there just was a new roll-out of the electricity meters. Sweden moved from yearly-based metering to monthly-based metering only two years ago so it does not seem reasonable to change the meters again after so short period of time. (Lindgren 2011, interview). The idea of demand response is considered but it seems as something very abstract and far away.

Nevertheless, there are examples from many countries where demand response is implemented without hourly based metering or advanced systems and it seems to be working fine for the big industrial customers. Demand response is in that case handled with contracts that state that the big customer must reduce the consumption during the critical peaks. This is the way demand response works now in Sweden and in Finland. The question is how to get the small customers to take part in demand response and if that actually is necessary. There should be contracts like this also between DSO and the small customers in order to lower the loads by agreements. Then DSO could control the loads in order to optimise the network. It has to be somehow a win – win situation. To make customers act they have to gain something. When the amount of renewables increases the volatility for the system will increase, too and that might create problems in balancing. The DSOs have to build and reinforce the lines or they have to make more use of the demand response. This works only with dynamic prices. If the customers have a flat rate tariff they will not be exposed to the peaks and will not be incentivised to react to fluctuations. The problem is that dynamic prices are needed but then it has to be sure that the customers understand the importance that if they promise to act they really have to do that. If the customers do not react the supplier will have to buy more electricity from the market to cover the extra consumption that was not supposed to happen and the DSO will not gain any benefits for the system. This makes everything more expensive for all the parties. (Kolessar 2011, interview)

Suppliers' interest is to minimise the risk. They also need the demand response. Suppliers could aggregate the demand response offers and sell them to those who need it, the DSOs for example. If the customers have a flat-rate tariff with incentives for demand response they could be activated to act and in that way the supplier could reduce the risk. On the other hand, if the customer has a flat-rate tariff it already includes the risk share in it so the main gain would be for the DSOs. (Kolessar 2011, interview)

As the home automation systems that enable the demand response for household customers are expensive it is not cost efficient to build them to old houses. The wiring should be renewed from the start and a new electricity board is needed. The automation could be handled wirelessly too, but still new equipment is needed. The price for the demand response equipment becomes lower when the equipment is installed at the construction phase of the new building. Then owners of the old houses do not have the equal possibilities to participate to the demand response as the cost for them would be so much higher compared to the owners of the new houses. This puts the customers in different position which is not fair. In the vision of the Omakotiliitto (Finnish House Owners' Association) in the year 2050 half of the houses that exist then are already build before 2011. One incentive for this situation could be the tax credit for domestic help. The system seemed to work for encouraging people to invest in alternative heating systems instead of oil and direct electric heating. (Hokka 2011, interview)

7.1.4 DSO's role in developing new services

The services that require sophisticated house automation are quite expensive and difficult to develop so they would probably cost something for the customer. Having an external service provider other than DSO to take care of this business would be a good option even though as the meter belongs to the DSO it would be quite natural for the DSO to own the external displays and the systems, too. In addition, the market model expects all the activity to be competed so there could be separate companies providing these display devices. (Sihvola 2010, interview)

The opinion of the regulator both in Finland and in Sweden is that these extra devices or services should be offered by some third party. There will be problems if DSOs starts to develop their own services and products. It could be harmful to the neutrality and indiscrimination aspect. In addition, this external business should be open for the competition. From a company that acts as monopoly it is crucial to have similar service neglecting the location where the customer lives. There is a risk that if the DSO starts to develop the services and only some of the customers use them, the cost of the development and using will be added to the tariffs for all customers to pay. If there were many different extra services would the DSO drift too much away from the core business that is actually the distribution of electricity? If DSOs still want to develop these extra services they should be unbundled from the normal distribution operation and the costs should be taken only from those who use the service and not put the costs in the tariffs. (Värilä 2011, interview) DSO should be an enabler providing the structure, platform and infrastructure so these extra services would be possible but it should not take the leading role. DSO can still be reimbursed from the service providers who use DSO's grid and metering data. This could lead to lower tariffs even. The DSOs can and should develop the grid that can help them to run the network better but they cannot take part in the parallel activity and make money with it. (Kolessar 2011, interview)

Some discussions have indicated that customers would prefer that it was DSO who offers these products or services rather than supplier. The customers do not want any other party to have access to their consumption data that is regarded as private somehow and as DSO already has access in it because the electricity meter belongs to DSO, it would be natural for DSO to have the role. In addition, as DSO has the monopolistic role and one cannot choose the DSO it seems better to have the DSO providing these services. If it was the supplier and then you want to change supplier it would be difficult to decide how to handle the changing of the equipment or services. (Svalstedt 2011, interview)

Peak shaving and demand response functions are also something that DSO surely wants to control but these functions should not be integrated to the electricity meter. The devices that handle these could be plugged in so that the other market actors could provide devices for the customers too and not only DSO. If there were real time displays for showing the consumption values they should be connected to the electricity meter directly. If the data had to be collected and validated by the DSO in between it would never be real time information. To have it in real-time the values should be taken from the meter and displayed immediately. The connection could be the form of USB or something equivalent so that the raw metering data could be obtained by any service provider. The demand response products should not be monopolist's role. The products should be out in the market and for clients to choose what they want and they can choose if they want to pay for the products. These products should be available for any-one to provide and not only for the supplier or the DSO. It could also be DSO but not as part of the network business. Then the extra business should be unbundled somehow from the network business at least from the accounting. The core business of DSO will be more limited in the future when the SCM is implied. (Richert 2011, interview)

There already exist service providers. For example some DSOs have outsourced the metering to another company. They pay that the service provider maintains the meters and collects the values. In addition, there exists some alarm services already. For DSO this starts to be already a lost opportunity. The external service providers can offer their services cheaper and then there would not be the dilemma if this should fit to DSOs role offering services like this. (Englund 2011, interview). At the moment the supplier com-panies do not have the technical competence to be the interface to the customer in de-mand response matter. The data of the smart meter is needed and the steering knowledge that the DSOs have. The information between the supplier and DSO should flow very fluently to make demand response possible. (Willerström 2011, interview). Anytime there is a player that is artificially put between those who have the real interest in the transaction the transaction costs will increase. It has to be thought who have the real incentive in the market. So adding third market parties just to get more competition to the market might not always be the best option. The DSO's role is still unclear. Should DSO act just as a platform for the other market actors or actively develop services? (Nilsson, M. 2011, interview)

The DSOs could be referred to a transportation company. It has to have the logistics, the capacity and it has to be in time. There must be a good back up system for delivering the values to the supplier and providing the good quality electricity to the customer. This is enough. Developing the products around the metering values can be done by some-body else. The role of DSO is complicated in the developing market. The DSO has the key to lead the development with smart meter but as the business is regulated because of the monopoly position it is difficult to steer the development of the smart grids when they have a leading position in it. This is why the state's promotion and positive attitude towards developing is necessary. It has to be thought of what should be the minimum that DSO should provide in developing the smart grids. If other market participants are investing a lot and others not at all it will be difficult for smart grid markets to develop if the "transportation" cannot be trusted. Then if the basics do not work what is the point of developing products or services? This would be harmful for the smart grid invest-ments. DSO does the investments but the profitability of those will be splitted to the other market participants too. (Willerström 2011, interview)

If the DSO puts really good equipment for automatic demand response they need to be let to earn money with it. Otherwise they would not have the incentive for it. Volatility of the prices that has increased in Denmark and Germany has put huge values at stake. The customers should neither be obliged to pay for the equipment. The obligation would give the signal that it is not valuable for the customers but the DSO has decided it is valuable. (Nilsson, M. 2011, interview)

One risk for DSOs is also that when they make it possible to connect small-scale production they give the customers too much independency. There could be other service providers with electricity storages and smart steering systems that make the DSO obsolete. Then DSO only has to provide the back up system and that system has still to be maintained so it works exactly then when it is needed. It could happen that if DSO invests in wrong places now there will be some negative consequences because the development runs over DSO. (Willerström 2011, interview)

7.2 Conclusions of the interviews

At the moment the incentives are not enough to make the small-scale production economically attractive. A person who takes up small-scale production has to have passion for it and not think of the profit as the payback period becomes so long. The equipment is still expensive. Most of all it is a favour to the environment but hopefully in the future the small-scale production will survive on its own and be competitive alternative in the market. In addition, the connection process should be made easier and harmonised more in the Nordic countries. For a small-scale producer it is difficult to find out what is needed in order to start up small-scale production. A practical way to advice the customer who is thinking of these questions would be a simple To Do -list that could be easily found from the web page of the DSO. At the moment DSO's sites include connection contracts and terms of network services that are not so easily understandable for normal customers. From the sites of ET and Suomen tuulivoimayhdistys ry. (The Finnish Wind Power Association) proper instructions how the customer should proceed if he wants to start small-scale production can be found though. It would be easier if this information was available at the DSO's site too as DSO is the preliminary contact for the customer in this process.

In United Kingdom the atmosphere has been pro smart grids for years. Some problems have also occurred as the regulation suggested that the metering roll out is managed by the supplier. The best way is that DSO handles it. (Söderbom 2011, interview)

The industry is in the point where we have to do some solutions for the distribution grid in order to provide solutions for smarter grid. Handling wind power or demand response and things like that will require certain investments that are fairly difficult to get back. Regulatory bodies should allow these investments and enable tariff increases for example. (Söderbom 2011, interview) It is a better way to give the incentive for each smart meter installed rather than force the DSOs to install the meters to every house. The result will be that the roll-out is done in much more smarter way than if it was obliged. In the long run the DSO would be back to the normal profits and could scale down the tariffs. (Nilsson, M. 2011, interview) One thing that also should be considered is the cost of the renewable production for the whole society. DSOs need to invest to the network so the small-scale production can be connected when wanted. DSO has to bear the costs by itself or then it might show in the tariffs. How are the costs shared? Eventually somebody will pay the costs of updating the grid. (Lähdeaho 2011, interview)

All in all, it seems that in Sweden the industry believes more to market driven development. If there is a chance to earn money there will be products and development without having the need to push the development with regulation. In Finland on the contrary, the industry is waiting for the regulation to draw the rules before decisions are done. They are more afraid of having developed something in vain if finally the regulation suggests that the responsibility of developing belongs to somebody else. The feed-in tariffs in renewable power are an example of this. The industry was waiting the feed-in tariff law to be legitimate before any further investigations were made. The Finnish law of having 80 % of the sites among hourly-based metering in 2014 is also an example of this. In Sweden they are not following the EU directive so strictly but it has been suggested to introduce the hourly-based metering to the sites where the yearly consumption is more than 8000 kWh or when the site has production of its own. Another suggestion has been to let the customer choose if he wants to get a smart meter regardless of the consumption. The rarity of the hourly-based metering has led to that that the demand response does not seem as attractive as in Finland as it would definitely require hourly-based metering. In Sweden the DSOs are questioning why they should invest huge amounts of money to something that is not necessarily needed. For a big customer the hourly-based metering is reasonable but not for the customers living in flats. Collecting the metering values costs money and the maintaining of the meter too. (Englund 2011, interview)

In Finland Vattenfall Verkko Oy decided to install smart meters to all the sites before there was a law that obliged for it. The change was made voluntarily. At the moment practically all the sites are being measured by hourly basis. In Sweden on the other hand when considering the next step after estimation invoicing there was a law that made the DSOs install the monthly reading meters. This turned out to be a wrong approach. The meters that were installed in 2010 are out of date already. As the meters were changed so recently it would be too expensive to start to change them now to more modern meters. People are thinking that hourly based metering does not bring so many benefits to the small customers and that they can do with the old meters as well. Nevertheless, customers cannot need or claim smart meters if they do not know what functions and services it enables. The faster the meters are changed to new ones the better. Smart meters create the platform for smart grids and services that may have not been even thought of. Even though they do not bring instant benefits it is good to be prepared at least to this extend. The hourly based metering will likely become compulsory in Sweden too but being a pioneer and acting before obligations might be a smart move.

Being the pioneer in the DSO field is an advantage. Then the company is a step ahead compared to the others and can plan its operations for longer term while others are still busy with surviving the previous step as installing the smart meters. This position brings credibility and in that way it is easier to make one's opinions taken into account when negotiating with other parties of the industry such as regulators. The decision to change to hourly based metering in time proved to be a good move for Vattenfall Verkko Oy. The meters could be tested in action and this was also useful for defining the asset base for the regulation model.

When considering purely demand response and not the other possibilities the smart meter brings it can also be thought that in order to get the wanted results to the market by demand response it is not necessary to get all the customers to participate. If the objective is just to get rid of the high peaks it would be enough to get response from maybe 5 – 10 % of the consumers. The biggest customers are enough as the small ones cannot contribute that much to the electricity market prices or the loads in the electricity lines. (Nilsson, M. 2011, interview) In addition to this, the equipment for demand response would be quite expensive so there would be only the very interested small customers that would take up demand response and want to install the equipment. To have decent equipment it would cost more than 100 € which is really the minimum for having some sort of display, metering, computer for storing the data and the device for receiving and sending the signals. A proper set of these would cost maybe around 500 €. To earn this money by demand responding the pay back time would be so long that it is not really economically wise. (Richert 2011, interview). In addition getting all the smallest customers to react could be a bit difficult. It could be hard to make them all watch the Nord Pool prices when the savings they can make are so small when they have so small consumption. For example, when the parents come back from work they still want to play console games with their children rather than save a euro or two. So getting maybe 10 % of the customers active is enough. These 10 % could get some sort of incentive from the DSO. Still in the market there would be enough price volatility to encourage to the demand response because of the large amount of wind power. (Nilsson, M. 2011, interview) So in case of the small customers demand response is rather for fore runners who are interested in energy efficiency and following their consumption. On the other hand from the environmental perspective the demand response option should reach all the customers in the long run because that is the key to energy efficiency. The energy efficiency concept should be introduced to normal households. When the people get their mind set for energy efficiency the demand response can be build into the system. (Willerström 2011, interview). At least the possibility for demand response should be offered to all the customers and when providing the hourly based metering DSO has already done its share. The rest is up to the customer's activity and the services that are offered by the supplier or some third market party.

One of the worries is that the regulatory organisations, the government and the industry want to define smart grids too soon in a way of trying to foresee what happens next in their development. It can be a restraint for the development of smart grids. One should rely more on the historical fact that where there is a change to earn money people will start to be more innovative and with this market based development there will be better solutions and products than if the development was conducted by the regulation. So instead of guessing what will happen if the electricity market prices will be very volatile or if there will be many EVs whose batteries can be used for storing electricity the network must just be prepared for multi-directional power flow. The top-down approach is that the solution is needed before. The innovations are happening rather in the laboratories and in the field rather than in the minds of the bureaucrats or the top management. So when they try to decide and regulate the direction of the development the best possible results are not always obtained. The regulator institutes both in Finland and in Sweden are understaffed. They do not have the technical expertise or the R&D that the companies have. Exaggerated by generalisation it could be said that the regulators should not act like engineers telling the industry what to invent but rather they should be economists who will decide about the incentives and the economic enabling of the market. The engineering should be left to the companies who have interests and resources for making new inventions. Then the happening of the innovations would be market driven. (Nilsson, M. 2011, interview). In other words the important thing is to think how the grid can receive and transmit information and handle the power flow to different directions and not to think what the actual inventions will be like. The available market opportunities will finally take care of what sort of products and services there will be. The task of DSOs it to enable the development by providing a functioning network and offering market place to others.

7.3 Summary

In general the electricity market works well. There are enough participants to ensure there is competition though some of the largest producers can still affect the prices too much. Most of the electricity that is sold in Nordic countries is exchanged in Nord Pool. This gives the market transparency and shows that the price is set in the market and not by the companies themselves.

Supplier centric model is seen somewhat as a risk for the functionality of the market if it makes it too difficult for small suppliers to compete. SCM is simple for the customers to understand and for the sake of the functionality of the electricity market it is important that the customers understand how the market works. The price areas also increase the understanding of the customers about the price forming. In addition they give correct signals where the production should concentrate. This is important for the small-scale production.

To support the small-scale production different incentive methods are considered. Netting the consumption and the production would be the most beneficial and the most simple way to contribute small-scale production but because of the taxation laws this will not be possible in the near future. In addition to the incentives there should be clear instructions how to proceed if one wants to become a small-scale producer. Now the DSOs work in different ways in this matter.

The small-scale production or demand response for small customers is not economically paying off. These are more for forerunners who are really interested about environmental issues or electricity business. The big industrial customers have been using demand response for years already.

Instead of taking the leading role in developing new services with smart grids the DSO should concentrate in its core business and operate as a transportation company of the electricity. Nevertheless, the electricity grid is in a state that it needs investments to bear all the new connections and functions that the smart grids require. DSOs should be encouraged to do these investments to secure the development of the smart grids.

The development of the products and services should be let to happen through a market. If there is demand for some specific service and a chance to make money with it there will surely be supply for it sooner or later. Market based development leads to better results than the development with regulation.

8 CONCLUSIONS

There are many ways to define the functionality of the electricity market. In this thesis the smart grids are presented from the perspective to make the electricity market function better. The smart grids are also needed to meet the EUs environmental 20-20-20 objective of cutting down the energy consumption by 20 %, increasing the production with the renewable energy sources to 20 % and increasing the energy efficiency by 20 % by the year 2020. The supplier centric model where the majority of the contacts would happen through the supplier and where DSO would act in the background creates new challenges to the smart grids. With SCM the roles of the actors will change. The regulation also has an important part in supporting the smart grids.

In this thesis work the two cases of small-scale production and the demand response are considered. The material is based on the 25 specialist interviews that were executed in Finland and in Sweden. The findings from the interviews suggest that at the moment the small-scale production is not profitable for the producer. That is why several incentive systems are considered though in the long run the small-scale production should live in the market with its own merits without incentive systems. Some incentive systems were seen working better than others. For example the obligation of the supplier or the DSO to buy the electricity produced by the renewables did not seem like a good way to promote small-scale production. Most of the electricity the small-scale producer produces is used to cover the own consumption of the customer. The left-over electricity is fed to the grid. All the interviewees were supporting the netting method. There the customer could store the extra production to the grid and use it later without paying the taxes of it. This would not work because of the tax law both in Finland and in Sweden even though it is the best way for the customer and the industry and it could make people more interested about the small-scale production. The feed-in tariff that will be paid in Finland starting from July 2011 is a good way to incentivise to larger-scale production with renewables but it will not work for small-scale producers. On the other hand, small-scale producers are not only after profit but they are rather pioneers or early adopters who have the passion for environmental issues or are after independency from the electricity grid. Nevertheless, the distribution grid is needed for the back up.

Another case that was studied in this thesis is demand response. Traditionally the electricity consumption has not been adapting to the prices in the market and it has been only the supply that has regulated the consumption. With the help of smart meter that can measure the values on hourly basis and services built around it the customers have the possibility to follow their own consumption. The main problem that hinders the demand response is the lack of products. It is not clear yet who is allowed to develop products and services around demand response. The roles of the DSO, the supplier and the third market parties need better definition. On the other hand it would be good that the parties who really have the interest in regulating the demand would be those that can offer the services. The national regulation authorities both in Finland and in Sweden nevertheless want to keep the role of the DSO as only the electricity transporter who does not make profit with these extra services. In this way it would be logical if it was the supplier who would build the products and services but sometimes the goals of the supplier and the DSO can be contradictory. This might happen in a situation when there is lots of renewable production available so the electricity price is low and encourages increasing the consumption but at the same time the electricity lines might be heavily loaded. Then DSO has the interest to steer people to consume less but the market gives the signal that it is good to consume and load the batteries of the EVs for example. To steer the people towards lighter load consumption the DSOs are developing the price tariffs to more power based direction. The tariffs traditionally consist of a fixed fee that is set according to the fuse size and the second part of the tariff is based on the consumption and it is measured in kWh:s. In the future the fixed fee at least could be replaced with the power based part that would be measured in kW. These power tariffs are already in use for the industrial customers. The Finnish dual-time tariff is an example of a simple demand response system.

These two cases of connecting small-scale production and demand response both help in making the electricity market function better. With small-scale production the customers have the possibility to choose whether they want to participate to the market and there will be more participants in the electricity market. Demand response makes the electricity price adjust there where it is closer to the real price of the product as the demand side adapts to the price. In addition, when the load is lower the peak power plants that use fossil fuels are not needed to cover the peak consumption which makes demand response an environmental act too. All this is possible because of the hourly based metering of the smart meter that is provided by the DSO.

DSO enables the electricity market by offering the smart meter and by developing the grid so that connecting smalls-scale production and demand response is possible. The market opportunities decide what kind of products there finally will be around these two cases. It is important that the market based development is not restricted by the too strict decisions of the authorities. DSOs should be let to invest to the network in order to get the smart grids fully implemented.

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