IMPACTS OF LARGE-SCALE WIND POWER PRODUCTION ON THE FINNISH ELECTRICITY MARKETS

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In response to the threatening climate change, EU has set Finland an obligation to increase the share of renewable energy sources to 33 % of total electricity consumption by 2020. In order to fill this obligation, the installed wind power capacity would have to increase from approximately 110 MW today to 2 000 MW by 2020.

The objective of this research is to study the impacts of increased wind power production on the Finnish electricity markets. More precisely, consideration will be given to the wind power production's possible impacts on CO_2 emissions, public support costs and functioning of the electricity market. In regard to the functioning of the market, attention will be paid to spot prices, balancing power and transmission needs as well as competition. The aural and visual impacts of wind farms will be studied as well. In addition to the consequences of wind power, also the optimal support scheme to encourage wind power investments in Finland is discussed.

The study is carried out as a literature review. The references consist of a variety of academic articles together with Finnish statistics and non-academic studies from e.g. the International Energy Association and Pöyry Energy Oy.

The main findings of the study demonstrate that the most central impacts from increased wind power production in Finland would be the reduction of CO_2 emissions by 4,2-4,8 % and public support costs. It is found that by 2020 the cumulative public support costs can range from 1,3 to 1,8 billion euros depending on the support scheme. Increasing wind power capacity would also increase negative local impacts from wind farms such as noise and landscape disamenities. The impact on spot prices would be lowering but small, around 0,3 – 1,2 €/MWh. Increased wind power capacity is unlikely to substantially increase reserve requirements in the power system by 2020, but it requires reinforcements of the national transmission grid and building of a new connection between the northern parts of Finland and Sweden. The impacts on competition are likely to be small even though wind power can replace some of the old capacity of production forms with high marginal costs. It is also found that the optimal support instrument for Finland depends on the objectives: if the most important goal is to rapidly increase capacity this could be best achieved by using feed-in tariffs, but in the long run a more cost-efficient way to support wind power would be developing current investment subsidy-based system further.

Keywords: Wind power, electricity market, merit order principle, feed-in tariff, investment subsidy, CO_2 emissions

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Henna Fränti

TUULIVOIMAN VAIKUTUS SUOMALAISIIN SÄHKÖMARKKINOIHIN

Vastatakseen uhkaavaan ilmastonmuutokseen EU on asettanut Suomelle velvoitteen nostaa uusiutuvien energialähteiden osuus 33 % sähkön kokonaiskulutuksesta. Jotta tähän tavoitteeseen voitaisiin päästä, olisi tuulivoimakapasiteetin Suomessa noustava nykyisestä 110 MW noin 2 000 MW vuoteen 2020 mennessä. Tämän tutkimuksen tavoitteena on kartoittaa lisääntyvän tuulivoiman tuotannon vaikutuksia suomalaisiin sähkömarkkinoihin. Tutkimuksessa tarkastellaan vaikutuksia hiilidioksidipäästöihin, tuulivoiman tukemisesta syntyneisiin kustannuksiin sekä sähkömarkkinoiden toimintaan, jonka osalta analysoidaan tuulivoiman vaikutusta sähkön spot-hintaan, kilpailuun, säätö- ja varavoiman tarpeisiin sekä sähkönsiirtokapasiteettiin. Lisäksi käsitellään tuulivoiman aiheuttamia melu- ja maisemahaittoja. Tuulivoiman vaikutusten analysoinnin lisäksi tutkimuksessa pohditaan, millainen tuulivoimainvestointeihin kannustava tukijärjestelmä sopisi Suomeen.

Tutkimus on toteutettu kirjallisuuskatsauksena ja lähdemateriaali koostuu akateemisista artikkeleista, tilastoista sekä mm. kansainvälisen energiajärjestö IEA:n ja Pöyry Energy Oy:n toteuttamista selvityksistä.

Tutkimuksen keskeisiä tuloksia on, että tuulivoiman suurimmat vaikutukset Suomessa olisivat hiilidioksidipäästöjen väheneminen 4,2-4,8 % sekä tuulivoiman tukemisesta syntyvät kustannukset. Vuoteen 2020 mennessä kumulatiivisten kustannusten arvioidaan olevan 1,3-1,8 miljardia euroa tukijärjestelmästä riippuen. Kasvava tuulivoimakapasiteetin myötä myös tuulivoimapuistojen aiheuttamat melu- ja maisemahaitat tulisivat lisääntymään. Tuulivoiman vaikutus spot-markkinoihin olisi hintoja alentava mutta pieni, noin 0,3 – 1,2 €/MWh. Vuoteen 2020 mennessä tuulivoima tuskin vaikuttaisi merkittävästi sähköreservien tarpeeseen, mutta vaatisi vahvistuksia kansalliseen sähkönsiirtoverkkoon sekä lisäyhteyden rakentamista Suomen ja Ruotsin pohjoisosien välille. Vaikutukset kilpailuun olisivat todennäköisesti pieniä vaikka tuulivoima saattaisi korvata sellaisten teknologioiden vanhaa kapasiteettia, joiden marginaalikustannukset ovat tuulivoimaa korkeammat.
Lisäksi tutkimuksessa havaitaan että Suomelle sopivin tuulivoiman tukimuoto riippuu tavoitteista: jos tärkeintä on vaan nopeasti lisätä kapasiteettia, syöttötariffit ovat paras ratkaisu. Pitkällä aikavälillä kustannustehokkaampaa olisi kuitenkin kehittää nykyistä investointitukiin perustuvaa järjestelmää.

Avainsanoja: Tuulivoima, sähkömarkkinat, merit order – periaate, syöttötariffi, investointituki, hiilidioksidipäästöt

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Units

kW	kilowatt	
MW	megawatt	= 1 000 kW
GW	gigawatt	= 1 000 MW
TW	terawatt	= 1 000 GW
kWh	kilowatt-hour	= 3 600 kJ
MWh	megawatt-hour	= 1 000 kWh
GWh	gigawatt-hour	= 1 000 MWh
TWh	terawatt-hour	= 1 000 GWh
Kg	kilogram	= 1 000 g
T	tonne	= 1 000 kg
Mt	million tons	= 10^9 kg

1 Introduction

1.1 Background and motivation

In the 1970s the oil crises prompted investigations into energy sources derived from other materials than fossil fuels. Wind power was one of the technologies explored but even though the windmill was not a novel idea, it was soon discovered that designing wind turbines that would be suited for large-scale electricity production was far more complicated than was initially expected. Despite technical development, wind power still has a rather marginal role in electricity production, mainly due to its high costs compared to more conventional electricity generation forms utilizing fossil fuels and nuclear power.

Today electricity generation is facing new challenges caused by the climate change. Conventional electricity generation still relies heavily on fossil fuels, but in order to combat climate change, CO_2 emissions need to be cut. In the European Union, renewable energy sources are seen as a one of the central means for this. Based on an edict from the commission of the European Union, Finland is obligated to increase the share of renewable electricity to 33 % of total consumption by 2020. The most significant increase should come from wind power, which at the moment has only a negligible role in the Finnish electricity market. In order to fill the EU obligations, installed wind power capacity should increase from approximately 110 MW today to 2 000 MW by 2020.

The Finnish electricity market has gone through significant changes during the past decades. Electricity is vital for the functioning of any modern society, and for this reason electricity generation and transmission have traditionally been under tight governmental control. In Finland this regulation was partly removed in the 1990s during an electricity market reform. Besides deregulation, the reform unbundled the actual power component of electricity from the transmission services and enabled competition in this area. In addition, Finland joined the common Nordic electricity market tied together by the power exchange Nord Pool.

Today, the most important energy sources in Finland are fossil fuels, nuclear power and hydropower. They are all characterized by centralized generation and easy controllability of production. Wind power, in turn, is characterized by distributed generation and intermittency of production. In addition, its marginal costs are close to zero. These differences mean that if wind power production would increase in the future, it could potentially reshape the electricity markets in several ways.

1.2 Objective and research question

This study investigates what impacts the increasing wind power production will have on the Finnish electricity markets. This question will be addressed from several aspects giving consideration to CO_2 emissions, aural and visual impacts of wind farms, public support costs, spot prices, balancing power, and transmission grid requirements, as well as competition. In addition to analyzing effects of wind power on the electricity markets, the optimal support scheme to encourage wind power investments in Finland is also discussed.

What this thesis is *not* about is assessing whether there is wind power potential in Finland. The approach is "what if"; therefore, the impacts of wind power on the electricity market are analyzed presuming that wind power would increase in the future. Similarly, the best policy to increase installed wind power capacity is discussed with the expectation that there is a need to increase it.

Even though the scope of the study is Finland, the common Nordic wholesale market requires that one has to take a broader look in order to understand the situation in Finland. Where it comes to support schemes, feed-in tariffs, tradable green certificates and investment subsidies will be explored.

1.3 Research method and limitations

This study is carried out as a literature review. Some data is analyzed with graphs and simple calculations. References consist of a variety of academic articles together with Finnish statistics and non-academic studies from e.g. International Energy Association and Pöyry Energy Oy.

The research focuses on analyzing impacts in a time period from present to year 2020. This time frame has been chosen for three reasons. The first is that it is very difficult to estimate how much the wind power capacity will increase in the future. Even the views of electricity sector experts in Finland are dramatically different from each other (Varho and Tapio 2005). For this reason, the time frame was chosen based on the EU obligations of increasing the share of renewable energy sources to 33 % of total electricity consumption by 2020. The second reason is that the further the impacts of wind power are analyzed, the more uncertainty there is also about related factors such as fossil fuel prices and climate change policies, which could also direct us to the direction of remarkably different wind power markets. The third reason for choosing the time frame until 2020 as a basis for analysis is purely methodological; in the earlier research the impacts are typically assessed in the time scale of around 10-15 years. However, some impacts, mainly on the power system, are considered in this study also from a longer perspective.

As this thesis attempts to assess the future impacts instead of looking back, there is naturally plenty of uncertainty involved. Development of wind power and other electricity generation technologies, prices of fossil fuels and the political decisions about how climate change will be addressed are examples of factors that can greatly affect how wind power will shape the electricity markets and also what kind of support scheme would be best suited for Finland.

Furthermore, the method used has its limitations; being a literature review, this study cannot be any more accurate than the references it is built on. Naturally, the aim has been to combine information from different sources in order to ensure that the limitations of a single reference would not be directly passed on to this study, at least without them being pointed out. Also, some shortcomings in the references have been overcome by modifying the results, for example by discounting. Nevertheless, there is not much earlier research available about some specific topics, which limits the discussion on them also in this study.

1.4 Main findings

The main findings of the study indicate that the most central impacts from increased wind power production in Finland would be the reduction of CO_2 emissions by 4,2-4,8 % and the costs from paid subsidies. It is found that by 2020 the cumulative costs from public support can range from 1,3 to 1,8 billion euros depending on the support scheme. Increasing wind power capacity would also increase negative local impacts from wind farms such as noise and landscape disamenities. Wind power would also decrease the spot prices of electricity in Nord Pool, but the change would be small, approximately 0,3 – 1,2 €/MWh. Increased wind power capacity is unlikely to substantially increase reserve requirements in the power system by 2020, but it requires reinforcements of the national transmission grid and building of a new connection between the northern parts of Finland and Sweden. The impacts on competition are likely to be small at the penetration levels discussed even though wind power can replace old capacity of production forms with high marginal costs.

It is also found that there is no clear-cut answer to what kind of support scheme would be best for Finland to encourage investments in wind power. All instruments have their advantages and disadvantages, so which is the best depends on the policymakers' objectives. If the most important goal is to rapidly increase installed wind power capacity, this could be best achieved by using feed-in tariffs. There is, however, a risk that the costs from feed-in tariffs turn out to be very high. In the long run a more cost-efficient and a less risky way to support wind power would be to develop the current investment subsidy-based system further.

1.5 Structure of the study

The rest of the study is structured as follows. The second chapter gives an overview of the electricity markets in Finland as well as the common Nordic wholesale market Nord Pool. In chapter three, the orientation of the Finnish energy policy is briefly described. Chapter four introduces wind power as an energy source, giving consideration to its development, functioning and associated cost. Chapter five discusses the role of subsidies in relation to wind power. The question of what kind of support scheme would be optimal in Finland in order to prompt increase in wind power capacity is also addressed. Chapter six analyzes the impacts of large-scale use of wind power, and chapter seven presents the results.

2 Electricity markets in Finland

In this chapter, the basic elements of the Finnish electricity markets are described briefly and some topics important to the objective of this study are examined in a more detailed way. To understand the Finnish electricity markets one also has to take a broader look and consider the market in Nordic countries, which is also introduced in this chapter.

2.1 Consumption and production

Even though Finland as well as other Nordic countries is relatively small population-wise, the electricity consumption is substantial. Reasons explaining the high per capita consumption include a cold climate with cold and dark winters, an extensive amount of energy intensive industry, and a high share of electricity in total energy consumption (Kara 2004).

The total electricity consumption in Finland amounted to 90 TWh in 2007 (Long-Term Climate and Energy Strategy 2008). Industry represents 54 %, agriculture and housing 25 %, and services 18 % of the total use. In recent years electricity consumption has been growing at 2-3 % pace annually (Energy Market Authority 2009). Due to being necessary for many activities of everyday life as well as in manufacturing, demand for electricity is rather inelastic and varies greatly depending on the season and weather as well as the level of industrial activity.

The electricity production in Finland is relatively well diversified. The most important production form is combined heat and power production[1] (CHP) with a 34 % share followed by nuclear power, which generates 29 % of the total electricity production. Condensing power[2] and hydropower both had an 18 % share in 2007. Wind power makes up only 0, 2 % of the total power generation. (Statistics Finland 2008)

The fuel mix is rather diverse, as well, with the fossil fuels coal, gas and oil making up the largest share, 45 % of total production (Statistics Finland 2008). They are used in combined heat and power plants as well as in condensing power generation. It is also noteworthy that in

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[1] Combined heat and power production refers to a steam power plant where part of the energy is used for electricity generation and some for another purpose, e.g. for district heating or as process steam for the industry.

[2] Condensing power means generation at a conventional steam power plant where the energy of the steam is used solely for electricity generation and where the steam is condensed to water after the turbine.

Finland 13% of electricity and 20 % of all energy is produced using biomass, a share that is higher than in any other member country of the International Energy Agency, IEA (IEA 2009a). Finland also imports electricity, but the generation form has not been taken into account in the statistics. In 2006 the share of imports of total electricity use was 12 % (IEA 2009b).

The Finnish production mix is rather different from that of the other Nordic countries. In Norway, nearly 100 % of electricity is generated using hydropower. Hydropower is important also in Sweden with a share of 50 % in the production mix, followed by nuclear power and CHP. In Denmark CHP is by far the most important electricity production mode. Figure 2-1 represents the production mixes in Nordic countries. (Nordel 2008)

Since electricity has to be generated at the very moment it is used and the demand is rather inelastic, the supply has to vary constantly to fill the demand. Different production forms have distinct cost structures; therefore on the grounds of cost efficiency, the power plants that have low operational costs are kept running all the time and those with higher marginal cost are turned on only when the demand for electricity is high. This is called *merit order* (Holttinen

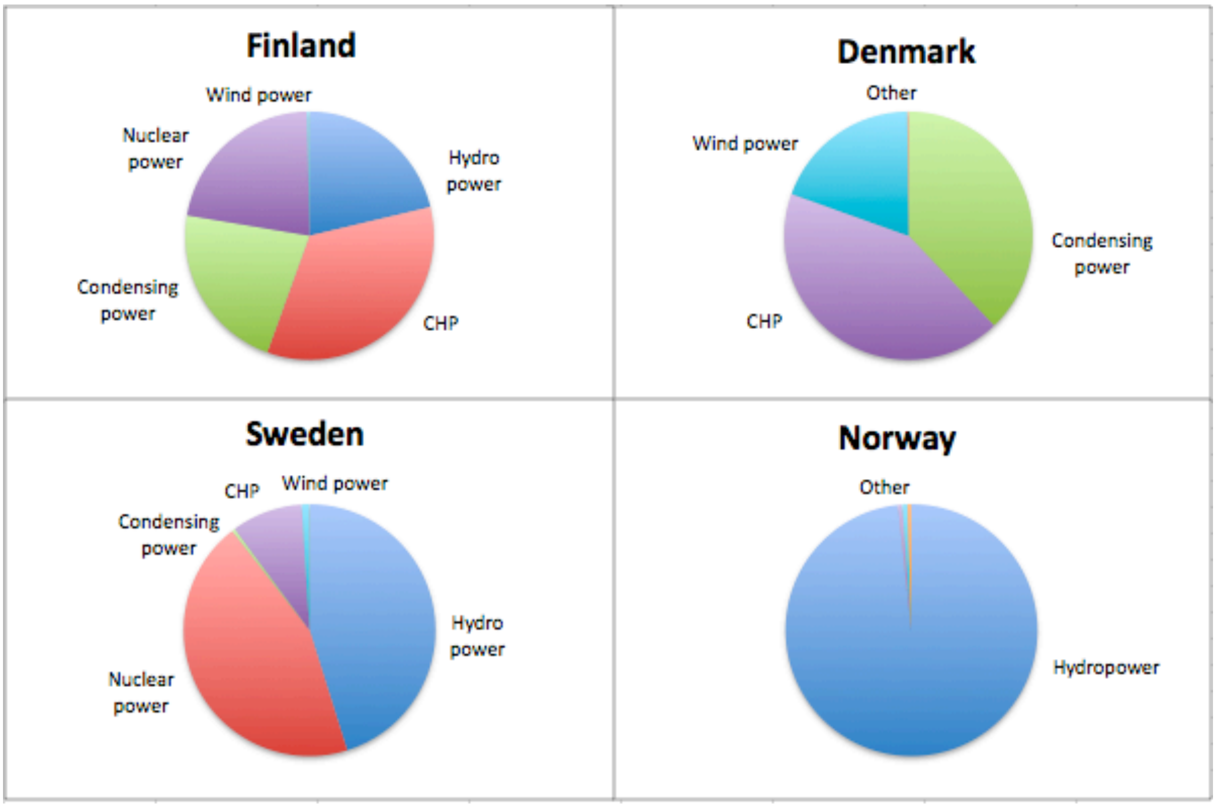

Figure 2-1. Electricity production in the Nordic countries. Source: Nordel (2008)

2004). The merit order principle together with distinct generation structures in Nordic countries are a central reasoning for the benefits that can be gained from a common Nordic electricity market. Chapter 2.4. will discuss this further.

2.2 Role of transmission

In addition to the power plants, the power system consists of a grid network through which electricity is distributed from the generator to the end customer. The Finnish grid network has four parts: the national main grid, regional and local grids, and transmission lines crossing the national borders to Russia, Sweden and Norway, through which imports and exports are handled (Kara 2004). The national main grid and the cross-border transmission lines are owned by Fingrid Oyj, which is in turn owned by the Finnish government along with the largest power companies such as Fortum Power and Heat Oy and Pohjolan Voima Oy (Fingrid Oyj 2009).

Fingrid operates as Finland's *transmission system operator* (TSO), which controls operational reserves and is responsible for handling non-predictable imbalances during operation that cannot be relieved by trade in the market. Fingrid is also responsible for financial settlement of these imbalances and building new transmission capacity. In addition to the operational reserves, also disturbance reserves are needed in the power system in order to avoid failures in electricity supply, which can have serious and costly consequences. The disturbance reserves are controlled by Fingrid, as well. (Fingrid Oyj 2009)

Electricity transmission is a natural monopoly for the reason that building separate parallel power grids is not reasonable. Before the electricity market deregulation in 1990s consumers had to buy their electricity from their local provider who owned the grid. During the market reform, transmission services were unbundled from the actual power component of electricity to remove obstacles to competition, and consumers were given an opportunity to buy the electricity from a vendor of their choice (Fingrid Oyj 2009). The electricity market reform will be further discussed in the next subsection of this chapter.

2.3 Nordic wholesale market Nord Pool

The Finnish electricity markets were liberalized gradually after 1995, when the Electricity Market Act (386/1995) took effect. Before that, the electricity business was coordinated by the government and operated by vertically integrated generation and transmission companies (Vattenfall 2009). An essential part of the electricity market reform was the establishing of the common Nordic wholesale electricity market, Nord Pool, together with Sweden, Norway and Denmark. Founded in 1996, Nord Pool was the first international commodity exchange for electricity in the world. Finland joined the Nordic power exchange market area two years later in 1998.

The main objective of the market reform was to take advantage of different generation structures between the Nordic countries (Carlsson 1999). The cross-border trade was intended to reduce regional price differences, enable the optimal use of resources and intensify competition in the market. Table 2-1 represents the history of the Finnish electricity market deregulation more closely.

Table 2-1. Electricity markets deregulation process in Finland. Source: Energy Market Authority (www.energiamarkkinavirasto.fi)

1.6.1995	The Electricity Market Act enters into force
1.6.1995	The Electricity Market Authority is set up
1.11.1995	All users with power demand exceeding 500 kW come within the scope of competition
16.8.1996	The Electricity Exchange EL-EX starts operation
1.1.1997	All electricity users are brought within the scope of competition.
1.7.1997	A national grid company, Finnish Power Grid Plc, is set up
15.6.1998	The Nordic electricity exchange, Nord Pool, starts operation in Finland
1.9.1998	Small-scale users (with a main fuse max 3x63 A and a power demand of max 45 kW), excluding leisure time residences and agricultural users, are allowed to avail of competition without an obligation to use hourly metering
1.11.1998	All small-scale users (with a main fuse max 3x63 A and a power demand of max 45 kW) are allowed to avail of competition without the obligation to use hourly metering
In 2004	Nearly 60% of electricity (energy) in Finland is bought with contract price. About 11% of customers have changed their electricity supplier

Nord Pool states its responsibilities include:

- Provide a neutral, transparent reference price for both the wholesale and retail markets
- Provide a reference price for power derivatives traded at the Nordic power exchange for financial contracts in Nord Pool ASA and bilaterally
- Serve as a grid congestion management tool
- Provide easy access to a physical trading at low transaction costs
- Create the possibility of balancing portfolios close to time of operation
- Promote inter-European cooperation through market coupling to Germany, the Netherlands and other European countries

Thus the purpose of Nord Pool is to offer a marketplace where electricity can be traded cost-effectively and where a transparent market price is formed. The market participants in Nord Pool are electricity producers, electricity companies and industrial enterprises from Nordic as well as some other countries. One has to be a member to trade in Nord Pool (Energy Market Authority 2009).

The marketplace for physical electricity in Nord Pool is Elspot, which is owned by the national TSOs: Norwegian Statnett SF, Swedish Svenska Kraftnät, Danish Energinet.dk and Finnish Fingrid Oyj. A possibility for balancing portfolios after the closing time of the Elspot, but at least one hour prior to delivery, is offered by the Elbas market, which is essentially an after-market for the Elspot. In addition, Nord Pool offers a market for financial contracts that can be used for hedging and speculation. (Nord Pool Spot AS 2009)

2.3.1 Spot market

Elspot is a day-ahead physical-delivery power market, where hourly power contracts are traded. Participants submit bids for the 24 hours of the following day by noon, which is the time the market is cleared. After that Nord Pool calculates and announces the resulting prices for each hour. This is made by aggregating all the purchase and sell orders into supply and demand curves. The *system price* is found in the intersection of the curves when no transmission capacities have been taken into account. This is the reason why the system price is also called *unconstrained market clearing price*. The trading method is called *auction trading* or *simultaneous price setting*. (Nord Pool Spot AS 2009)

What is noteworthy here is that the price formation works, at least theoretically, the same way as the merit order explained earlier in chapter 2.2. Producers bid slightly higher than their marginal costs, because it is cost-effective to keep the production running as long as the price covers variable costs. When the market is cleared, the producers that offered the lowest bids come first. This ensures that the power resources in the Nordic area are utilized effectively.

Because the transmission capacity in the Nordic area is limited, price mechanism is used to relieve grid congestions. The geographical Elspot market area is divided into bidding areas. If the contractual electricity flow between certain areas exceeds the capacity allocated for Elspot by TSOs, these bidding areas form price areas where prices are formed separately. Finland makes up one bidding area, which means that the price in Finland can deviate from the system price (Nord Pool Spot AS 2009). Price formation will be further discussed in the following subsection of this chapter.

2.3.2 Price drivers of traded electricity

In 2007 69 % of the electricity used in Finland was acquired from Nord Pool (Fingrid Oyj 2009). However, also in the bilateral trade the prices are often guided by the Nord Pool system price, which practically determines the prevailing price level. Figure 2-2 shows the Elspot system prices and Elspot regional prices in Finland from 1998 onwards. As can be seen in the figure, there has been an upward trend in the electricity prices during the past decade. Liski (2006) suggests that this might be due to three factors. Firstly, there has been a clear upward trend in the prices of fuel used in the electricity generation. Secondly, the Nordic electricity markets are getting more integrated into the Central European markets, where the production costs are higher. Thirdly, European Union Greenhouse Gas Emission Trading System (EU ETS) has brought a new cost factor to the supply side of the market. According to Honkatukia et al. (2006), approximately 75-95 % of the price changes in the EU ETS are passed on to the Nord Pool spot prices. This is possible due to highly inelastic demand.

What is also evident from figure 2-2 is that the volatility of the system price has been substantial; the system price has ranged from less than 10 € all the way up to over 70 €. As mentioned earlier, Sweden and Norway rely heavily on hydropower, which leads up to the fact that over half of the electricity in the Nord Pool market is generated using it. The annual variation in reservoir can influx ±20 TWh, which is a substantial amount compared to

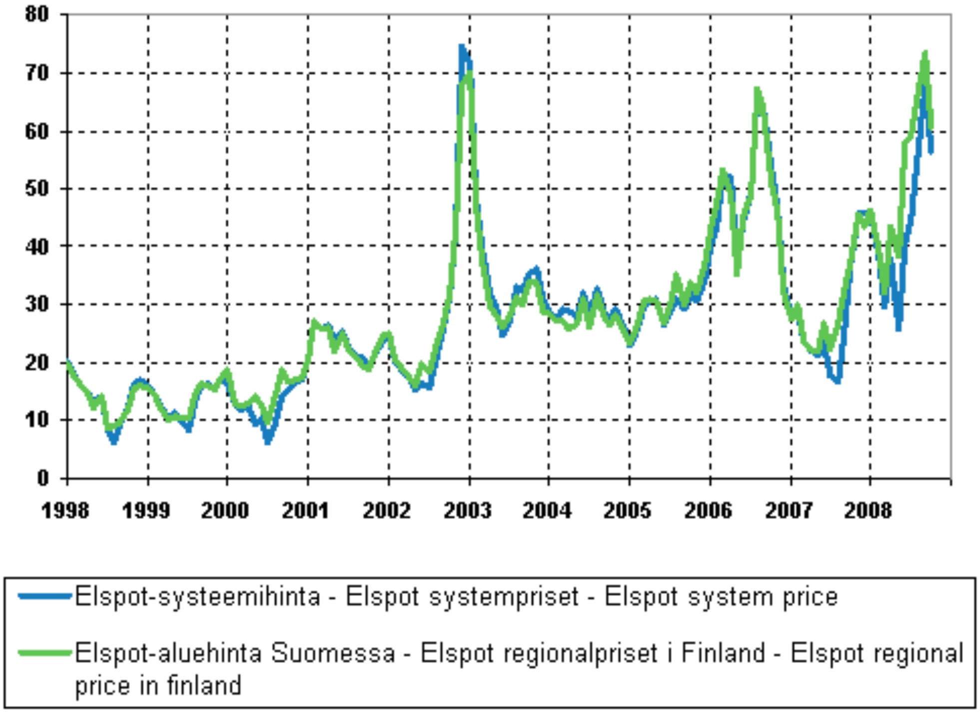

Figure 2-2. Average monthly spot prices at the Nord Pool power exchange 1998-, €/MWh. Source: Statistics Finland (2008)

the total production capacity of around 410 TWh (Laitasalo 2004). This makes the reservoir situation the most significant factor in the volatility of the electricity price. Dry years such as 2006 can be seen as a peak in the figure 2-2.

Figure 2-3. illustrates the production costs and capacity in the Nordic countries and explains more clearly the essential role of reservoir variation for the electricity price. As can be seen from the figure, hydropower comes on top of the merit order, that is, it has the lowest variable costs of the generation modes. Costs of other production modes can be tenfold, gas turbine being the most expensive and only rarely used. In a dry year when the reservoirs are low, the share of hydropower decreases and other production modes are utilized more. The system price is still the same for all regardless of the production mode. This creates price risk as well as opportunities for speculation by forecasting and estimating the reservoir situation level and the weather. Nord Pool offers financial instruments for this, which will be introduced next.

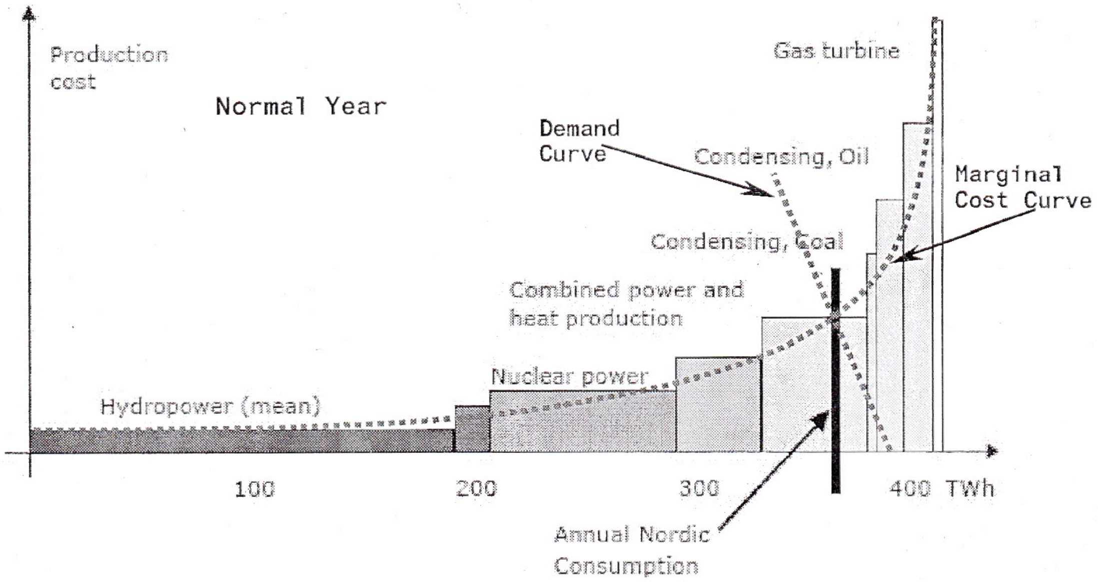

Figure 2-3. Merit order principle in the Nordic market. Source: Laitasalo (2004)

2.3.3 Financial market

Along with Elspot and Elbas, Nord Pool also offers a financial market for the power derivatives, which can be used for price hedging and risk management. Prices of the derivatives thus reflect market's beliefs about price development. In Nord Pool all derivatives are settled in cash, that is, there is no obligation to deliver the electricity but to pay the price difference between the contract and the realized system price. The Nord Pool financial exchange currently quotes futures, forwards, options and swaps for regional price differences, which are called contracts for difference. The maturities range up to four years.

Futures and *forwards* are both agreements to buy or sell an asset at a certain future time for a predetermined price. The seller of the contract assumes a short position and agrees to deliver the specified asset on future date for a certain price. Respectively, the buyer assumes a long position. If for example the asset price at maturity exceeds the delivery price in the contract, the one who has a short position suffers the losses and vice versa. (Hull 2005)

The difference between futures and forwards in the Nord Pool market lies in the way the financial settlements are done. For futures financial settlements include daily mark-to-market settlement, which means that the difference between today's and the previous day's market value is credited or debited from the buyer's and seller's accounts. This, in turn, means that margin calls are made occasionally should the balance of the account decrease sufficiently, and thus the long-term futures can potentially tie up a substantial amount of capital. In contrast, forward contracts involve no cash flow until the maturity. Furthermore, the time value of the cash flows affects the valuation of the futures but not forwards. (Laitasalo 2004)

Options in the Nord Pool financial market are so called European options, which means that they can be exercised only on the expiration date. They give a right but not an obligation to buy or sell an asset on a predefined date at a certain price. In fact, the same price hedge as with futures and forwards can be achieved by options, but the downside risk is limited. (Hull 2005)

Contract for difference (CFD) relates to the formation of area prices when there is insufficient transmission capacity between price areas. The reference price for financial contracts is usually the system price. However, the physical procurement is based on area prices. Due to this asymmetry, regular derivatives cannot perfectly hedge for price risk. CDF for the same period and volume can cover any price differential between a particular area price and the system price. (Korpinen 2004)

2.4 Competition

According to a review of IEA (2008), the Nordic electricity market is considered to be one of the most competitive electricity markets in the world. In the public discussion the functioning of the common Nordic market has, however, been questioned on the grounds of the increasing electricity prices and extensive company profits. This has led to political pressure to investigate the functioning of the market, and many studies such as Purasjoki (2006) have been conducted[3]. However, as Liski (2006) notes, there is a contradiction between the public image and these surveys. According to the surveys, the market seems to, for the most part, function as it is supposed to, which is the conclusion in Purasjoki's (2006) report as well.

In public discussion it is, however, deemed to be problematic that some producers are able to make big profits due to the price formation process where the market is balanced by one system price. From the point of view of economics the idea that the markets are not working

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[3] Academic research on the subject is unfortunately more exiguous, Liski (2006) being one of the exceptions.

because of the company profits is not justified. The definition of the efficiency of the markets is that the marginal costs of the last unit of product sold, not all the units, equal the price. This is exactly the outcome of trading in Nord Pool. In most of the markets the marginal costs are not constant but vary, both between producers and between units produced by one producer. This is the source of producer surplus in all the markets, not just in electricity. Surplus also has important implications to the functioning of the market, since it gives incentives to new producers to enter the market and the old producers to improve their production. Thus the trading system in Elspot indeed leads to an efficient outcome and producer surpluses should not be interpreted to indicate malfunctioning of the market. Of course, this does not mean that the outcome in the electricity market is necessarily good or desirable as these questions are purely normative. The trading system should, however, be criticized on the grounds of other arguments than efficiency.

This discussion has lately been further intensified by the debate of so-called *windfall profits*[4]. This term refers to the profits gained by mostly companies owing hydro and nuclear power capacity due to European Union emissions trading scheme, EU ETS. The EU ETS will be introduced in a more detailed way later in chapter 5.2, but it is relevant to mention here that this emissions trading scheme has added a new cost factor to the all the producers who use fossil fuels in their production, in Finland mostly condensing power and CHP. Even though at the early phase of the trading scheme most of the allowances are granted for free, their opportunity costs are added to the marginal costs of power production (Blanco and Rodrigues 2008). This means higher bids to Elspot, which leads to an increase in the system price. For the producers who have lower marginal costs than the production form on the margin this naturally means higher profits, which are called windfall profits. In the public discussion also the possibility of cutting off the gains with a so-called windfall tax has been raised.

This idea can be criticized on the grounds of the concept of efficiency discussed above, a well as on the grounds of incentives. The emissions trading scheme was designed to force companies to take social costs from CO_2 emissions into account and thus to encourage investments in cleaner technology. However, if the profits are cut off from the companies not using fossil fuels, there is no incentive to invest in environmentally sound technology. Also

[4] The etymology of the phrase windfall profit comes from the British colonial times, when the crown owned all the forests and the colonists were prohibited to use any lumber from them. The exception was trees falling on one's property due to an act of God such as a storm. The gains from using this lumber or selling it were called windfall profits to represent the idea that they came unexpectedly.

the argument that the windfall tax is reasonable because companies did not know that the use of fossil fuels would be subject to tradable allowances when they invested in hydro- and nuclear power in past is somewhat illogical. Does the fact that the old power plants were built when EU ETS did not exist make them less environmentally sound? Should environmentally friendly choices not be rewarded if they were made before they turned out to be economically beneficial as well?

Even though not all the arguments in public discussion are always reasonable from the point of view of economics, it is true that the competition in the electricity market is not unproblematic. After over 10 years of free competition, the Finnish electricity market structure still mirrors the time when local monopolies provided the market both in production and transmission of the electricity. In spite of approximately 120 companies engaged in electricity generation, the market could best be described as an oligopoly due to the strong position of two large groups, Fortum and Pohjolan Voima. Together these two account for 60 % of the power generation (Energy Market Authority 2009). Even though these large Finnish producers only have a reasonably small share of the common Nordic market, their relative importance increases when the price areas are formed and the market becomes more concentrated.

One of the obvious problems from the competition point of view is that Fortum and Pohjolan Voima together control half of the votes in the Finnish TSO Fingrid Oyj (Fingrid Oyj 2009). As mentioned earlier, electricity distribution is a natural monopoly and separated from the supply of the actual power component of electricity. It raises questions about the neutrality that in Finland, unlike in other Nordic countries, the national TSO is to a large extend in the hands of private producers. For example, Fingrid is responsible for building new cross-border transmission capacity. If it is possible to Fortum and Pohjolan Voima to get higher prices for their production when price areas are formed, it is unlikely that they have incentives to relieve grid congestions. (Liski 2006)

Liski (2006) also points out several factors that complicate evaluating competition in the Nordic electricity markets. Firstly, the day-ahead trading system leads to competition that is clearly based on neither price nor quantity. Secondly, a variety of production modes and especially a large amount of hydropower make assessing market power complicated. Most of the time the production mode on the margin is some other than hydropower. This theoretically gives large hydropower producers especially in Norway and Sweden an opportunity to increase price level by constraining their supply when other production with higher marginal costs is needed more. Whether hydropower producers actually do this is as yet unclear and very difficult to investigate because market power cannot be detected from a difference between marginal costs and price. Finally, the group of market participants in Nord Pool is rather stable and their interaction frequent. This creates nearly ideal conditions for informal agreement on prices, which is, however, very difficult to observe.

Electricity retail in Finland is mainly carried out by local supply companies that sell electricity they have generated or purchased from the wholesale market. After the deregulation also some foreign companies, for example Swedish Vattenfall and German E.ON, have entered the Finnish retail market. In recent years also major electricity producers such as Fortum Power and Heat Oy have become interested in electricity retail and gained a significant share of the market (Energy Market Authority 2009).

From the customer's point of view there are no physical barriers to switching supplier, except the time and inconvenience it takes and the fact that changing supplier often means that the customer ends up with separate bills for supply and distribution (Lewis et al. 2004). However, only 4.3 per cent of Finnish electricity customers had switched their supplier in 2007 (Energy Market Authority 2009). Even though low switching activity per se does not necessarily indicate malfunctioning of the retail market, combined with the almost nonexistent correlation between wholesale spot price and retail price it raises questions (NordREG 2005). It seems that consumers are acting irrationally seeing that only so few have changed their electricity provider after the market reform even though savings could have been gained by doing so. This has puzzled many researchers, but thus far no clear reason has been found to explain this.

Korpinen (2004) concludes that customer satisfaction does not explain switching behavior since while satisfaction may not keep customers, dissatisfaction may not lose them. Furthermore, customers are surprisingly tolerant to rough price increases even when they are not in line with the wholesale market prices. The theory of economics claims that the more homogenous the product is, the more indifferent consumers should be between choices and thus be prone to choose the most inexpensive supplier. It would, however, seem that contrary to the theory, the homogeneity of electricity could add friction to the market as consumers do not believe they could gain anything by changing the supplier (Korpinen 2004). One explanation to low switching activity could also be the so-called *status quo bias*, which means that whatever the current situation is, it is preferred to another, perhaps more rational alternative. This could be due to perceived risk associated with changing (the current choice might not be good but at least the customers know what they get) or simply the mental effort needed to change. In any case, people are prone to cling to status quo even though by changing the supplier they could improve their situation. It may also be the case that even though some savings could be gained by switching electricity producers, the overall price level is still considered to be so low that consumers do not pay much attention to their electricity bills.

To summarize, the common Nordic electricity market mainly functions well and this leads to an efficient balance of supply and demand. However, insufficient transmission capacity often causes Finland to become a pricing area on its own, which makes market more concentrated and potentially gives big market participants such as Fortum an opportunity to use market power. Use of market power is, however, very difficult to observe because of the variety of different production modes in the market. In the retail market there are no physical barriers to competition, but the low correlation between wholesale spot prices and retail prices in addition to low supplier switching rates might be a signal of malfunctioning of the market. More academic research is needed for uncovering the obstacles for competition both in wholesale and retail markets.

3 Orientation of the Finnish energy policy

Despite the deregulation of the electricity market in 1990s, government still has its role in the development of the market e.g. by having a vote in Fingrid, granting permissions to build new nuclear power plants and deciding on possible support schemes for different energy forms. Government's impact may even strengthen in the coming years due to the increasing need to respond to the climate change in ways that are not possible without government interference. In this chapter are described the broad guidelines of the Finnish energy policy in order to give the reader an overview of the set objectives and how government plans to reach them. It should, however, be kept in mind that political decisions are always subject to change and the results of this study apply whether these objectives remain the same or not.

Finnish energy- and climate-related policy objectives are currently expressed in the Long-Term Climate and Energy Strategy (Pitkän aikavälin ilmasto- ja energiastrategia). The Finnish energy policy is strongly affected by the aims and obligations of the European Union, which in turn is influenced by wider international cooperation such as the Kyoto protocol. International agreements will shape the guidelines of the Finnish policy also in the future, and the United Nations' climate convention that will be held in Copenhagen at the end of year 2009 will have a strong impact on the energy policy after 2012 when the current Kyoto protocol will come to an end.

According to the Long-Term Climate and Energy Strategy (2008), the main goals of the Finnish energy policy are to secure the availability of energy in all circumstances, stabilize and eventually reduce total energy use and to increase the share of renewable energy sources to 38 % of total energy use by 2020. The following closer discussion about these three objectives is based on this strategy if not mentioned otherwise and will focus on electricity.

3.1 Security of supply

Security of supply is a highly important question to any nation today because the functioning of the society is dependent on the availability of reasonably priced energy. Finland is strongly dependent on energy imports because over two thirds of the total energy is brought from abroad. All fossil fuels, as well as uranium fuel used in nuclear power plants are imported. A further concern to Finland is that all the natural gas, nearly all oil and 10 % of electricity is imported form a single source, Russia.

Where it comes to electricity, the Finnish self-sufficiency is on a better level. There are, however, still concerns that need to be addressed in the future. Net imports of electricity can reach up to 20 % of total consumption (IEA 2009a), and, as already mentioned, approximately half of this comes from Russia. The Russian imports are uncertain already in the near future because the energy consumption in St. Petersburg region is growing faster than production capacity. The rest of the imports come from other Nordic countries either through bilateral trade or the Nord Pool power exchange. In the future there will also be a possibility to import electricity from the Baltic countries when a new transmission line Estlink cable will be finished (IEA 2009a). With a capacity of 350-MW, it will, for the first time, link the power grids of Estonia, Latvia and Lithuania to the western European grids.

According to the Long-Term Climate and Energy Strategy (2008), Finland's objective is to ensure sufficient domestic resources to cover whole electricity demand also in a situation where imports are not possible due to unexceptional weather or other kinds of difficult circumstances. The opening of a new 1600-MW nuclear power plant, Olkiluoto 3, will enhance the supply security (IEA 2009a), but even more new domestic capacity is needed to reach the target. There is, however, no specific plan on how it will be obtained.

3.2 Energy use stabilization

In Finland the total use of primary energy was 302 TWh in 2005, and the demand for energy is still increasing. In the Long-Term Climate and Energy Strategy (2008) it has been forecasted that if no new actions are taken, total energy use will grow to 347 TWh by 2020. The government's goal is to restrict growth so that in 2020 the total use of energy is at the most 310 TWh. For electricity the forecast is that the total use will grow from 90 TWh in 2007 to 103 TWh in 2020. The objective is to limit this growth so that the total use of electricity will not be more than 98 TWh in 2020.

The policy goals are very ambitious seeing that Finland is already one of the leading countries when it comes to energy efficiency of e.g. manufacturing and construction (Kara 2004). The concrete means to achieve this target are still under political consideration, even though the broad guidelines and some measures are already expressed in the Long-Term Climate and Energy Strategy (2008). The main principles are to support further development of technology and innovations as well as to promote education, communication and consultation. The public support for energy- and climate-related technology and innovations will be doubled by 2020.

3.3 Renewable energy sources

In Finland the share of renewable energy sources was 28,5 % of the total energy consumption in 2005. This is the fourth-highest share among IEA-countries and mainly based on extensive use of biomass and hydropower (IEA 2009a). The policy objective stated in the Long-Term Climate and Energy Strategy (2008) is to increase the share of renewable energy sources to 38 % of total energy use by 2020. For electricity this means that the share of renewables should be increased from 29 % in 2007 to 33 % by 2020. The most substantial increase should come from wind power, for which the objective is to increase installed capacity from around 110 MW to 2 000 MW by 2020. With this capacity the annual wind power production would be ca. 6 TWh.

As stated in the strategy, Finnish natural resources enable the increasing the use of renewable energy and electricity, but to achieve this, changes are needed in the present support schemes and institutions. This is particularly true for increasing the use of wind power, whose share is now very moderate (IEA 2009a). According to the strategy, feed-in tariffs will be introduced in Finland to promote wind energy. This support scheme is chosen because multiplying budgeted funds for wind power is considered to be politically impossible, whereas in feed-in tariff system the funding comes directly from consumers. The details of the support scheme are still open, and decisions will most likely be made by March 2010 when the EU-countries are obligated to submit their national action plans to raise the share of renewable energy. The design of an optimal support scheme will be discussed later in chapter 5.5.

4 Wind power as an energy source

This chapter will introduce wind power as an energy source giving consideration to its development, functioning and associated cost. In addition, the current situation in Finland will be introduced. Being an economics study, technical attributes will be described only to the extend that is necessary for the understanding of this research.

4.1 Brief history

In the 1970s the first oil crisis prompted investigations into energy sources derived from other materials than fossil fuels. Wind power was one of the technologies explored but even though windmills were not a novel idea, it was soon discovered that designing wind turbines that would be suited for large-scale electricity production was far more complicated and expensive than initially expected. The knowledge base during that time was rudimentary, but after the first national R&D projects demonstrated that existing knowledge of meteorology, electrical machinery and other related science could also be applied in wind engineering, wind energy research organizations started working in association with meteorological and aeronautical research institutes and universities. First commercial turbines appeared on the market in 1980, around the same time when Denmark and California witnessed a boom in the demand for small turbines (50-200 kW) and first MW-class demonstration programs were started in the United States, Germany, Denmark and Sweden. Despite good market conditions, many companies went bankrupt owing to technical problems. (OECD 2006)

During the late 1980s and early 1990s demand for wind power increased, mainly due to subsidies and tax credits. The technology could not yet compete economically without governmental support. Wind turbines were now installed in small groups called wind farms and national R&D programs promoted the trend towards larger turbines of around 500 kW. At the end of 1990s, wind turbines at favorable sites finally started to become cost competitive with fossil fuels and nuclear power. (OECD 2006)

Mainly after the end of the 1990s, a new global concern, climate change, entered into the public discussion. Nowadays there is a wide consensus among researchers that climate is warming at an accelerating pace (IPCC 2007). The change is mainly caused by human actions: changes in land use and especially the use of fossil fuels that releases CO^2-emissions to the atmosphere (Stern 2007). In Finland, the energy sector is the most significant source of

CO_2 emissions with over 83 % of total emissions (IEA 2009a).

Due to the central role of the energy sector, environmental concerns have given wind power a big boost. Combined with increasing fossil fuel prices, countries are becoming more interested in using alternative energy sources that help to limit CO_2 emissions. The increase in the installed wind power capacity has been rapid during the past decade and in 2007 the cumulative capacity in the world was already 93 710 MW, showing over 26 % increase from the previous year (IEA 2008). Figure 4-1 represents the increase in the installed capacity and electricity generation in IEA member-countries, which together account for 80 % of the total installed capacity in the world.

Despite fast growth, wind power still has considerable technological and economic challenges ahead. According to IEA, the priority research areas in the future are continuing cost reductions, decreasing uncertainties, enabling large-scale use and to minimizing environmental impacts (OECD 2006).

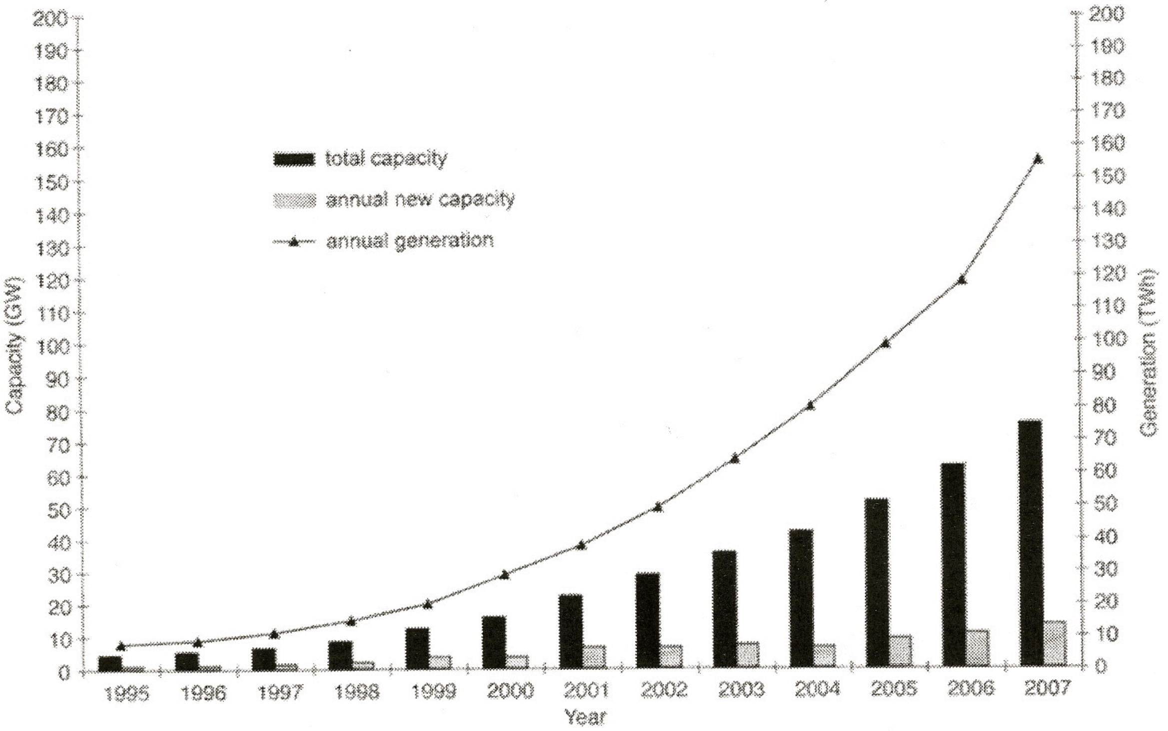

Figure 4-1. Annual installed wind power capacity, cumulative installed wind power capacity, and annual generation as reported by the IEA Wind member countries 1995–2007. Source: International Energy Agency (2008)

4.2 Basic information

The definition of wind power is simply an energy production form converting the kinetic energy of moving air masses into electricity. Using air as fuel has some important advantages: it is free, inexhaustible and produces no emissions. This makes wind power an attractive alternative when CO_2-emissions have to be cut in order to tackle the climate change. Practically zero marginal costs put wind power on top of the merit order, which gives wind power producers an opportunity to sell their production whenever it is available.

Using wind to generate electricity has disadvantages, as well. Most importantly, wind varies greatly and cannot be controlled. This brings about great challenges to technology and means that wind power cannot be used as a single source of electricity, but always needs backup power to compensate for the periods of low wind. Fortunately, these problems can be greatly reduced by large geographical spreading of wind power, which also reduces risk of near zero or peak output. In addition to being variable, wind is also hard to predict in advance. This causes problems for wind power producers when they sell electricity in the Elspot market. As described earlier, the market for next day is cleared at noon, which means that producers should be able to forecast their production 12-36 hours in advance. For wind power this is a real challenge, which will be discussed later.

One further difficulty in using wind power is finding favorable sites. Wind power is characterized by distributed generation, as compared to other electricity production forms production capacity of one power plant is rather small. This means that in order to increase the share of wind power in total electricity generation, a large number of wind farms are needed. Wind resources vary widely even within small distances, and because the height of a windmill tower can nowadays be close to 100 meters, measuring wind intensity near the ground does not give reliable information about wind resources in the heights. An updated wind atlas that the Finnish Meteorological Institute will publish at the end of 2009 will greatly help in this respect. However, finding sites with good wind resources is not enough; they should also be approved for power plant purposes in the land use planning. Furthermore, local public can resist the project due to perceived risk of aural and visual impacts.

Difficulties in finding good sites on land have led to an increasing interest towards offshore wind farms. According to Rinta-Jouppi (2003), sea locations have many advantages:

- Better wind conditions, i.e. higher wind speed and less turbulence
- Possibility to build beyond visible horizon
- Possibility to place the turbines in optimum line
- No rent for the site
- Possibility to drive with higher tip speed, which means more noise but better efficiency

The disadvantage is that the foundation and assembly costs are considerably higher for offshore wind farms than for farms on land (Rinta-Jouppi 2003). However, the possibility for offshore locations increases wind power potential tremendously and will most likely make up a large share of new installed capacity in the future (OECD 2006).

4.3 Wind energy economics

The most significant obstacle to large-scale use of wind power is still its high costs, even though the cost of wind-generated electricity has fallen significantly over the past few decades driven by technological development, increased production levels and the use of larger turbines (OECD 2006). Even though wind power is already cost-competitive with other electricity generation forms in the most favorable sites, it still requires financial support in the majority of cases. This is particularly true for Finland where the market price of electricity is low when compared internationally.

Costs of wind power can be divided into:

- Investment costs
- Operating and maintenance costs
- Balancing costs

Investment costs include purchasing of the turbine and other parts, foundations and electrical infrastructure for the site as well as capital cost from financing the investment. Investment costs vary greatly depending on the local circumstances such as condition of the soil, roads, proximity of electrical grid sub-stations etc. The estimates of average costs vary between USD 1200/kW to USD 1550/kW of installed capacity (OECD 2006). This would mean that an installation of a 1 MW wind turbine would cost an average of 1,2 to 1,55 million USD, or respectively 0,96 to 1,2 million euros[5]. In installation costs economies of scale can be achieved by building wind farms, as connecting many turbines in the same location is clearly cheaper than having only one turbine.

Operating and maintenance costs include expenses related to repair, consumables such as brake pads or gearbox oil, insurance, site rental and administration. Wind turbines are typically designed for a lifespan of 20 years or more. On average, they perform well with only few operational difficulties. The modern wind farms typically achieve availability of more than 98 %, i.e. the turbines are ready to run more than 98 % of the time (OECD 2006). According to IEA, the estimations of yearly operating costs in different studies vary from 1-4.5 % of the investment costs, rising steadily along with turbine lifespan (OECD 2006). This pattern is also mentioned by Rinta-Jouppi (2003). Investment and operating cost together make up the production costs of the wind power.

It is noteworthy that the structure of production costs of wind power is very different from the power plants using fossil fuels. Investment costs are high making up over 80 % of the total production costs (Pöyry Energy Oy 2007), but once the power plant is in use, operating costs are low. This is contrary to power plants using fossil fuels, where fuel costs make up a large share of overall costs. Wind power, however, has higher *balancing costs* than more conventional generation forms due to the unpredictability of the wind.

Balancing costs are items related to the prediction errors of production. In general, the system operator wants to know the production for planning purposes already many hours in advance to the delivery. In Elspot the market for next day is cleared at noon for the bids for the 24 hours the following day, which means that producers should be able to forecast their production 12-36 hours in advance. According to Georgilakis (2008), in this time span it is reasonable to expect forecast errors of 10-15 % of the rated capacity of a wind park. Holttinen (2004) has studied the prediction errors in Denmark and found that when forecasting 6 hours ahead the error for the installed capacity of about 1900 MW wind power was between ± 100 MW for 61 % of the time. Errors of more than 500 MW occurred nearly 1 % of the time. When forecasting 36 hours ahead, the prediction errors grew and were between ± 100 MW 37 % of the time and ± 500 MW 7 % of the time.

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[5] Using the average USD/euro exchange rate 0,796 in 2006.

If the producer selling his production through Elspot fails to forecast his production accurately, he can trade the difference between the original bid and the more accurate prediction in Elbas market, which closes one hour prior the delivery. This can either add or reduce costs for the producer depending on whether he has to buy the missing production or has an opportunity to sell the surplus. If some difference between Elspot bid and production materializes, the system operator, in Finland Fingrid Oyj, covers the difference by using operational reserves and the costs are assigned to the producer. The cost of this regulatory power is higher than the market price for electricity because it is used at short intervals only and has to be kept available so that the production cannot be sold to the market. The higher price level of regulatory power gives market participants an incentive to maintain the power balance. The net income for the producer selling his production through Nord Pool equals Elspot income – net costs from Elbas – regulating costs. (Holttinen 2004)

Together all these costs determine the cost of electricity produced, which is the most relevant measure when it comes to the competitiveness of wind power compared to other production forms. Finding comparable estimations of costs of electricity produced is, however, difficult, because this is a commercial secret for private producers. Moreover, most of the figures do not take balancing cost into account, and therefore the real costs for the producers are in fact somewhat higher. According to IEA (2006), in the United States the cost of electricity ranges from extremely low 0,032 €//kWh to 0,048 €//kWh[6] if the site has excellent wind resources and the turbines are MW level. In IEA's (2006) study the costs in Finland are mentioned to be comparable. Benitez et al. (2008) estimate the costs of wind generated electricity to vary from 0,025 €/kWh to 0,046 €/kWh depending primarily on the wind resources of the site. Also Heptonstall (2006) presents somewhat similar figures, the median for onshore wind power being 0,024 €/kWh and offshore 0,033 €/kWh.

There is no Finnish academic research on research on the issue of costs, but some non-academic studies can give rough estimates. In its report to the Finnish Energy Industries (ET) Green Stream Network Oy (2007) approximates the costs to be 0,085 €/kWh for both on- and offshore wind power. In Pöyry Energy Oy's (2007) report for the Ministry of Trade and Industry the costs are estimated to be 0,082 €/kWh for onshore and 0,074 €/kWh for offshore

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[6] All the figures is this paragraph were transformed to €/kWh form using the fact MWh = 1 000 kWh and annual exchange rates published by the ECB in the year of the study in question. This might slightly distort the figures but seeing that the aim is to give rough estimates the method was justifiable to make figures comparable.

wind power. The higher costs for onshore projects reflect the assumption that there is more economic potential for wind power in sea areas than on land, where the project sizes have to be smaller.

Table 4-1 summarizes all these cost estimates and compares them to the costs of certain other production technologies estimated by Heptonstall (2006). It is apparent that wind power is more expensive than some more conventional technologies such as nuclear power. In addition, the Finnish cost estimates are much higher than other countries' estimates. Part of this difference is caused by the fact that the Finnish studies mentioned have included 12 % return on invested requirement in the cost calculations in order to reflect the costs for projects that need to be market-determined. The rest of the difference could reflect additional costs from local conditions such as cold climate or simply more conservative assumptions. However, the differences are substantial and academic research is required to find out the reasons for them.

Table 4-1. Cost estimates of wind-generated electricity, €/kWh

	€/kWh
Benitez et al. (2008)	
Wind power	0,025-0,046
IEA (2006)	
Wind power	0,032-0,048
Pöyry Energy Oy (2007)	
Wind power - onshore	0,082
Wind power - offshore	0,074
Green Stream Network Oy (2007)	
Wind power	0,085
Heptonstall (2006)	
Wind power - onshore	0,024
Wind power - offshore	0,033
Coal	0,022
Gas	0,021
Nuclear	0,021

4.4 Current status in Finland

At the moment, wind power has only a marginal role in the Finnish electricity markets. The total installed capacity amounted to 110 MW in 2007 and the total generation was 0,0188 TWh (IEA 2008). This makes up a share of only 0,2 % of the total electricity production. The progress in wind power capacity has been slow compared with other European countries. In

2007, there were 107 wind turbines in operation with the average turbine size being slightly over 1 MW (IEA 2008). Figure 4-2 shows the development of installed capacity and wind power production in Finland.

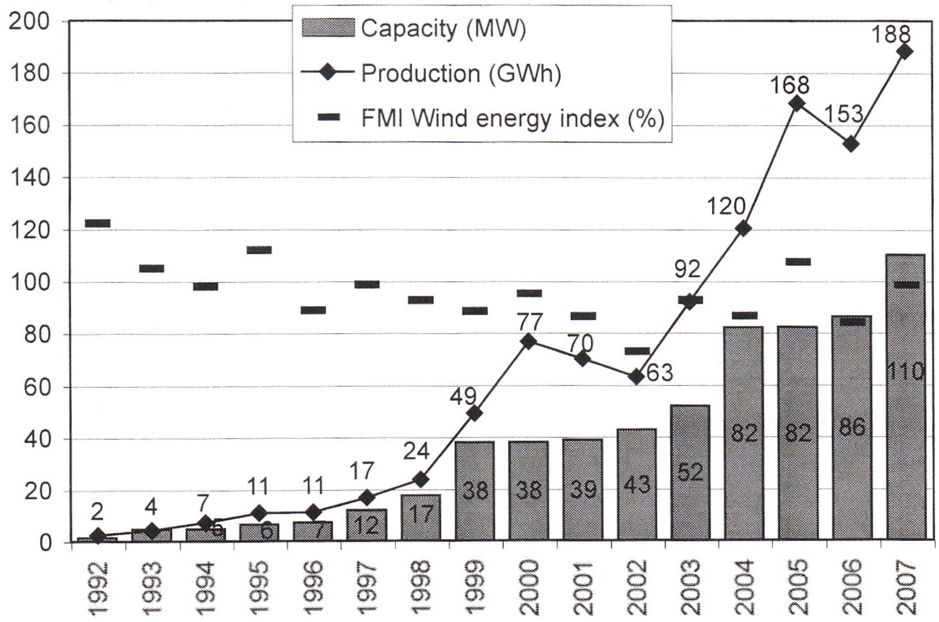

Figure 4-2. Development of installed wind power capacity (MW) at the end of year, yearly wind power production (GWh), and wind production index (calculated from Finnish Meteorological Institute wind-speed measurements converted to wind power production, 100% is average production for 1987–2001) Source: International Energy Agency (2008)

The wind turbines in Finland are mostly located on the coastal area. Figure 4-4 shows a map of wind power plants in Finland at the end of 2007. The coastal areas offer best potential also for the projects in the future (Pöyry Energy Oy 2007). On land, there are sites for few hundred megawatts identified in the regional land-use plans. Some of them are, however, not economically rational to use in the near future. Most of the potential is thus offshore, which is enabled by the long Finnish coastline with shallow waters. Almost 10 000 megawatts of offshore potential have been identified in the process of renewing regional plans. (IEA 2008)

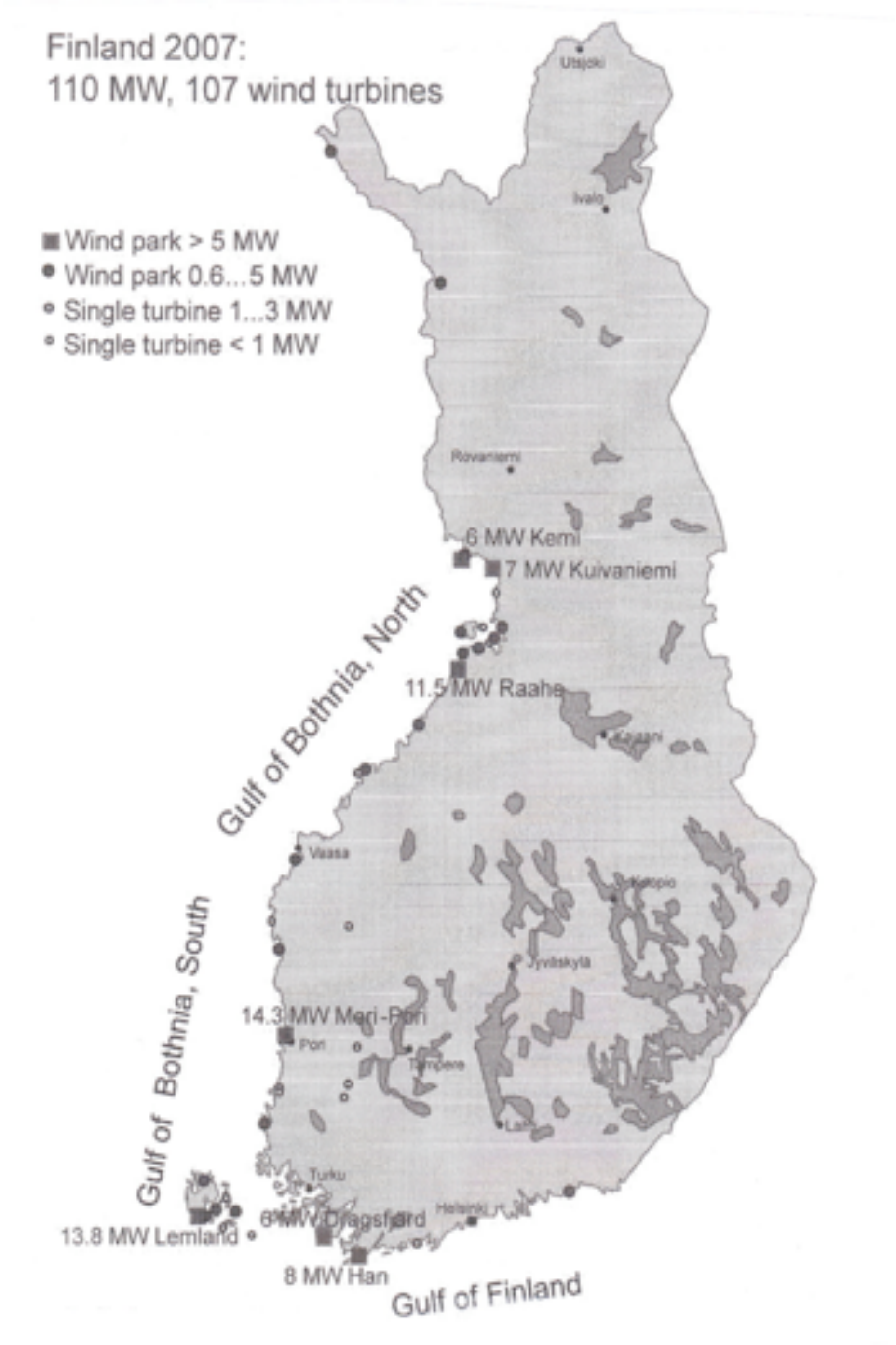

Figure 4-3. Finnish wind power plants at the end of 2007. Source: International Energy Agency (2008)

5 Role of subsidies in the wind power diffusion

In most of the countries, governments are, one way or another, involved in the development and diffusion of renewable energies. The role of governmental support in increasing the wind power capacity is introduced in this chapter. First are discussed the motivation for supporting wind power and the impact of EU ETS and after this, the support scheme currently in place in Finland is introduced briefly. Other policy instruments will be brought up as well and lastly the question of optimal support scheme for Finland is addressed.

5.1 Motivation for public support

As shown in the previous chapter, wind power is still more expensive than some conventional electricity generation forms, particularly nuclear power and the ones utilizing fossil fuels. So why should wind power be used in the first place? This question will be approached first from the customer's point of view and thereafter from a wider perspective.

Many electricity retailers in Finland offer wind-generated or "green" electricity that has been produced by renewable energy sources and is more expensive than the "regular" electricity. In a commodity like electricity, the marketing of this option is challenging; the product is identical to other alternatives except for the generation form used and the only difference consumers can see is in their electricity bill. In Finland the Finnish Association for Nature Conservation (Suomen luonnonsuojeluliitto SLL) has been granting a Norppa ecolabel for energy since 1998. The label is granted for electricity that is produced by wind power, renewable bioenergy, hydropower and photovoltaic, and companies can use it in their marketing for environmentally sound electricity.

Between 1998 and 2007 sales of Norppa labeled electricity has risen from 5 to 2667 GWh per year (SLL 2009). This is, however, less than 3 % of the total electricity consumption of 90 TWh in 2007 (Long-Term Climate and Energy Strategy 2008), indicating that most of the consumers are either not aware of this possibility or are not willing to pay more for an environmentally sound option. In the study from Varho and Tapio (2005), 14 Finnish electricity experts were interviewed about their views on the development of wind power in the future. The respondents were rather skeptical about the environmental consciousness in Finland and did not believe that more expensive wind-generated electricity would have a significant market share in the future (Varho and Tapio 2005). It thus seems likely that even though “green” electricity has its niche in the market, large-scale production of wind power would mean that most of the wind-generated electricity would need to be sold as “regular” electricity without a price premium. As production costs of wind power are higher than its competitors’, this means that public support is needed if investments in wind power are to be increased.

From the economics point of view, the answer to the question why wind power should be subsidized lies in the externalities of fossil fuels. Unlike electricity generation forms utilizing fossil fuels, wind power produces no CO_2 emissions. CO_2 is a global pollutant that spreads around the atmosphere regardless where it is emitted. It is also the largest contributor to the climate change (IPCC 2007). This means that electricity production using fossil fuels causes substantial social costs that are not considered by the producers. The basic principle of externalities is illustrated in figure 5-1. In the figure supply 1 refers to a situation where producers set their supply without taking the social costs of externalities into account. If these costs are included, supply curve moves upwards (supply 2), and in the equilibrium the price is higher and the traded quantity thus lower than when the externalities were excluded. This demonstrates that if the social costs of CO_2 emissions were included in the prices of fossil fuels, wind power would likely be much more competitive also cost-wise. This gives rationale for government interference in the markets.

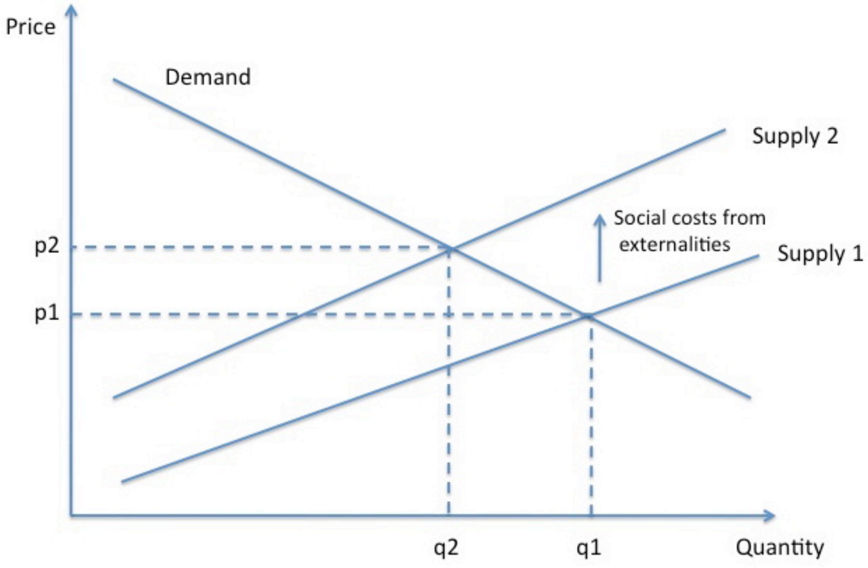

Figure 5-1. The impact of externalities on the market equilibrium.

In addition to negative externalities of fossil fuels, there are certain other factors advocating the use of wind power. Firstly, the electricity produced by wind power is domestic. This makes it attractive from the security of supply point of view. Secondly, compared to nuclear power, another CO_2 free technology, it has no security risks and is partly because of that much easier to promote politically. Thirdly, it has potential to promote growth and bring jobs. As can be seen from figure 5-2, Finnish wind energy sector turnover was around 500 million Euros in 2007, most of this coming from exports (IEA 2008).

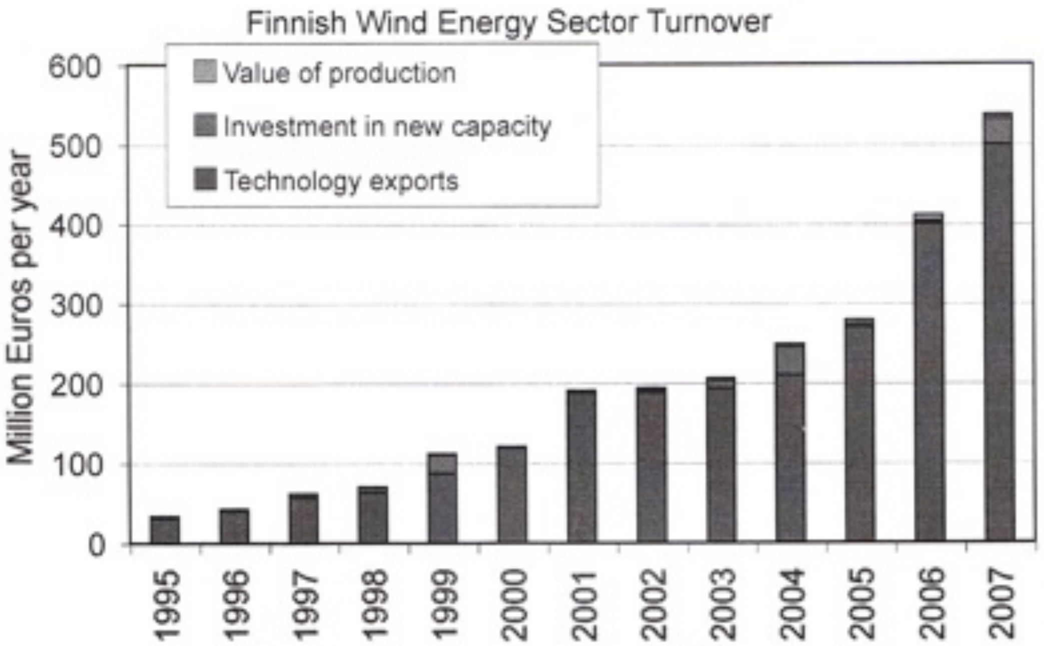

Figure 5-2. Finnish wind-sector turnover: wind power technology exports, investments, and production turnover. Turnover from electricity production sales has been estimated from the average spot price. Source: International Energy Agency (2008)

The public support for renewable energy seems even more admissible when taking into account that they are competing on an unequal market with more conventional energy sources (Blanco and Rodrigues 2008). In total, fossil fuels receive substantially more governmental support than renewable energies. This support can be either explicit, e.g. support for nuclear research, or implicit such as funding of energy infrastructure. In Europe the amount of the subsidies to renewable energy is only 19 % of total governmental support to the energy sector and almost three quarters are directed to different fossil fuel alternatives (EEA 2004). Of course, instead of establishing new subsidies for renewable energy it could also be supported by stopping subsidies for other energy sources. This would, however, be politically very difficult and due to society's heavy dependency on reasonably priced electricity, governments are often willing to maintain their influence in the sector.

5.2 The impact of emission trading

Before moving on to the situation in Finland, one question needs to be addressed: why is there a need for any support schemes in Europe where the EU ETS is in effect? EU ETS was introduced in 2005 by the European Union in order to help member states to achieve compliance with their commitments under the Kyoto Protocol by setting up an internal market where companies could trade CO_2 permits (Blanco and Rodrigues 2008). The idea is to issue allowances corresponding to the amount of accepted CO_2 –emission and then give firms an opportunity to trade them so that emission cuts will be made where it is most cost-efficient. In principle there should thus be a market price for the CO_2-emissions and electricity prices should mirror their true (social) costs when companies are forced to take externalities into account. This should improve the cost competitiveness of wind power and other renewable energy sources and eliminate the need for other subsidies.

The practice has, however, been very different. Blanco and Rodrigues (2008) discuss problems of EU ETS and point out several factors that have led to the failure of the system to encourage investments in wind power and other clean energy sources. One of them is national political influence and over-allocation of permits. Member countries had significant freedom in designing the National Allocation Plans, NAPs, which has brought about conflicts of interest, because countries also had strong incentives to estimate their future needs as high as possible. This lead to an over-allocation of the permits that in turn provoked a collapse in the prices of permits in 2006. In the spring 2006 the CO_2 prices was less than 10 €/tCO_2 and by the end of 2006 they fell below 1 €/tCO_2. This over-allocation has hampered incentives to invest in new technologies, since most of the companies did not have to make any changes in their current production process in order to meet the target they have been assigned (Blanco and Rodrigues 2008). In the spring 2009 when this study was written the price was again ranging between 10 and 16 €/tCO_2 (Vertis Zrt. 2006).

The second drawback of the EU ETS mentioned by Blanco and Rodrigues (2008) is the initial allocation method. In the first phase between 2005 and 2007, 95 % of the permits were granted for free and in the second phase between 2008 and 2012 the share decreased slightly to 90 %. As mentioned earlier, in the electricity market prices are set relative to marginal costs, which include opportunity costs for the certificates although they were granted for free.

This means that electricity prices have gone up after the EU ETS took effect in 2005. According to Honkatukia et al. (2006), approximately 75-95 % of the price changes in the EU ETS are passed on to the Nord Pool spot prices. This is possible due to highly inelastic demand. In addition, the producers now receive a higher price for their entire production even if the new cost factor, CO_2-certificates, only applies to production that utilizes fossil fuels. This mechanism produces windfall gains. However, Blanco and Rodrigues (2008) do not point out clearly in their study that this increase in the electricity prices and windfall profits actually affect incentives to invest in new technologies positively. Producers get higher price for their merchandise, which makes more projects profitable. On the grounds of some other aspects, windfall profits and rise in the electricity prices can of course be considered negative outcomes, but for the development of new technology their impact is clearly positive.

In conclusion, even though the EU ETS could in principle eliminate the need for other subsidies, the issue is in practice more complicated. The reason for the EU ETS failing to encourage investments in wind power is twofold. Firstly, EU ETS is only concerned about decreasing CO_2 emissions and does not take other advantages of wind power (e.g. security of supply) into account. Secondly, the poor implementation has hampered the working of the system, over-allocation of the certificates being the most significant problem.

5.3 Current support scheme in Finland

In Finland the current support scheme for wind power is based on investment subsidies. Depending on the level of novelty, an investment subsidy of up to 40 % may be awarded. Between 2001 and 2006, an average subsidy of 35 % was received by the projects that applied for it. In addition, a tax refund of 6,9 €/ MWh is awarded to wind power producers (IEA 2008). It is noteworthy that in the current system only the tax refund is dependent on the actual production. Investment subsidies are granted based on project plans before the implementation of the project, but paid based on materialized costs.

The current support scheme has several drawbacks. There is always uncertainty about the granted subsidy level, which complicates project planning. It also makes it difficult for the projects to get financing from external sources, which means that in practice only companies with strong balance sheets can carry out new projects (GreenStream Network Oy 2007). This also means that the average size of projects remains rather small, because the larger the project, the higher the risk. The project size is also constrained by the annual budgeted funds because they might be too small to grant large projects adequate investment subsidy. The largest projects are, however, the projects that will most likely be the most successful in economic terms since sharing high fixed costs requires sufficient capacity. At the same time, the level of the subsidy, even when granted in maximum of 40 %, is deemed to be too low to encourage large-scale investments (see e.g. Pöyry Energy Oy 2007, GreenStream Network Oy 2007, IEA 2009a). It seems clear that the current support scheme is not sufficient considering the ambitious target of increasing installed wind power capacity to 2 000 MW by 2020.

In the Long-Term Climate and Energy Strategy (2008) the government announces a plan to establish a new support scheme based on feed-in tariffs. The reason for replacing the current R&D based system with feed-in tariffs is told to be the financing: radically increasing budgeted funds for wind power support is deemed impossible, but feed-in tariffs are financed through payments coming directly from electricity users. The concept of feed-in tariffs is introduced next along with some other possible policy instruments to support wind power. Lastly, the question of a suitable support scheme for Finland will be discussed in the final subsection of this chapter.

5.4 Policy instruments

In nearly all industrialized and also in many other countries wind power is already supported by the government. According to IEA (2008), most often used incentives are direct capital investments as subsidies for projects, providing a premium price for electricity generated by wind (feed-in tariffs), obliging utilities to purchase renewable energy (tradable green-certificates) and providing a free market for green electricity. Also R&D funding is a common way to support wind power. In Europe, 19 EU-member countries out of 27 used some kind of feed-in-tariff scheme (Blanco and Rodrigues 2008). Finland is currently not one of them, but there are plans to implement feed-in tariff system also in Finland (Long-Term Climate and Energy Strategy 2008).

All the support instruments have their advantages and disadvantages, and the best alternative depends on the local circumstances and the policymakers' objective. When designing a support scheme to liberalized electricity market such as the Nordic market there is also one further difficulty. In order to make support scheme as effective as possible, policymakers should be able to take the interaction of different national schemes into account (OPTRES 2006). In the common Nordic market all the countries are currently having their own different support schemes for renewable energies. This does not lead to optimal use of power resources since new wind farms are not necessarily located in the most efficient way and the most inefficient old power plants are not replaced (OPTRES 2006).

There is, however, one central problem in setting up a common support scheme in the Nordic region. Even though countries could agree on financing the feed-in tariffs and regulatory costs, the distribution of achieved CO_2 reductions would be politically very challenging at the current situation where the climate policy goals and EU obligations are national. The policy makers of a country where new projects would not be located would probably not be willing to finance increase in renewable energy in another country. The common policy instruments are thus most likely not topical in the Nordic market in near future despite the higher level of efficiency that could be reached by harmonized policies.

5.4.1 Feed-in tariffs

Feed-in tariffs are systems where a certain price is guaranteed to producers leaving the quantity of production to the market to decide (Varho 2006). The system can be designed in many ways that can roughly be divided into two categories: fixed feed-in tariffs and premium feed-in tariffs.

Fixed feed-in tariffs refer to a system where electricity producers are guaranteed a fixed price for their production. Usually this functions by the TSO buying wind-generated electricity from producers at a set price and selling it further to the spot market on market price. The resulting loss is covered by payments collected in transmission bills. The problem is that producers do not have any market risk, which reduces their incentives to react to market signals e.g. by striving to reduce costs. The system where the producers do not sell their products on the market also limits the number of market participants and can thus hinder functioning of the market. At the same time the system offers government a very strong control. Fixed feed-in tariff system is currently in effect in e.g. Germany (Klessman et al. 2008) and was used in Denmark in the 1990s (Munksgaard and Morthorst 2008).

Premium feed-in tariffs is a system where a premium is paid to producers on top of the market price. The premium is usually paid by the TSO, who collects the needed sum in transmission bills. The TSO has usually no obligation to buy wind-generated electricity from producers, but they sell their production directly on the spot market. In this system wind power producers face the normal market risks of e.g. decreasing spot prices. Unlike in fixed tariff system, the producers also usually pay the balancing costs and thus have an incentive to forecast their production as well as possible. Premium feed-in tariffs system is at the moment in use in e.g. Spain where each producer can choose whether they want a fixed or a premium-based system (Klessman et al. 2008).

The greatest challenge of feed-in tariffs, both in fixed and premium ones, is setting the tariff on the right level where producers' incentives are strong enough to encourage new investments without the system burdening electricity users with too heavy costs. In practice the tariffs are set differently depending on the age, location and technology of the power plant in most systems currently in use (Greenstream Network Oy 2007). The tariff level is also typically guaranteed to producers for a rather long time, usually for 7 to 20 years (Greenstream Network Oy 2007). This lowers the risk for investors, but causes problems for policymakers in finding the right tariff level. It is a very challenging task since in addition to subsidies both the market price for electricity and development of production costs affect the competitiveness of wind power. The higher the price for electricity rises and the more production costs can be reduced, the fewer subsidies are needed in order to increase wind power capacity. Furthermore, the electricity price is in turn heavily dependent on the prices of CO_2 certificates (Pöyry Energy Oy 2007).

In a study by Neij (1997), experience curves are used to analyze the prospects for diffusion of renewable energy technologies with special emphasis on wind power. The concept of experience curve is simple: it describes how unit costs decline with cumulative production. The idea of experience curve is often expressed by progress ratio (PR), which gives the progress of cost reductions for different technologies. For wind power the study assumes a PR of 96 %, which means that costs decline by 4 % each time the cumulative installed capacity doubles (Neij 1997). In the report for the Ministry of Trade and Industry, Pöyry Energy Oy (2007) introduces a hypothesis that the PR for wind power would be 85 %. Already these two studies demonstrate that there are very different estimates for how fast the costs of wind-generated electricity can be brought down.

Predicting future electricity prices is not much easier. In the Nordic market, forward and future prices present the market's prediction of the future price development, but as discussed in chapter 2.4.4, there is considerable uncertainty in prices depending mostly on rainfall that cannot be forecasted accurately. Furthermore, futures and forwards can be used to get predictions of prices only up to four years, whereas support schemes have to be designed for a longer period in order to be effective. The importance of continuity is stressed by Fuss et al. (2008), who came to a conclusion that it is better to have a policy that is stable over a certain length of time and then changes abruptly than less abrupt but more frequently changing policies. It is noteworthy that in addition to the fact that predicting future electricity prices and production costs is difficult, information is also asymmetric. Policymakers do not have as accurate information of production costs as producers, who in turn have an incentive to overstate them.

In general, feed-in tariffs are deemed to be an effective tool in increasing the use of wind power, mostly due to good results in countries like Germany, Spain and Denmark (GreenStream Network Oy 2007). For example in Germany the installed wind power capacity increased from 2080 MW in 1997 to 22 247 MW in 2007 after a feed-in tariff scheme was implemented (Bundesverband Windenergie 2009). The development was somewhat similar in Spain where feed-in tariffs were introduced in 1998. The installed wind power capacity grew from 839 MW in 1998 to 15 145 MW in 2007 (Asociación Empresarial Eólica 2008 cited by Klessman et al. 2008). However, there are also less successful examples of feed-in tariff schemes. For example in France and Austria feed-in tariffs have not led to a significant increase in wind power capacity. The reasons for this are probably the low level of tariffs, too short duration of the system or different kinds of limitations to projects accepted in to the system (GreenStream Network Oy 2007).

In research also the central role of market conditions on designing a feed-in tariff system is widely emphasized. The openness and competitiveness of the market and current wind power penetration have a great impact on what kind of support scheme is the most suitable. In addition to the level of feed-in tariffs, policy-makers' have to decide e.g. to what extend are wind power projects exposed to costs from balancing and grid reinforcements. For example Klessman et al. (2008) have studied support schemes in Germany, Spain and UK in order to define the pros and cons of exposing renewable energy projects to market risks. In the low-risk approach producers are not exposed to price risk but guaranteed a fixed feed-in tariff. In addition, a TSO centrally forecasts production and pays the costs of balancing as well as grid reinforcements. From policy maker's point of view there is a trade-off between high-risk and low-risk approaches. In high-risk scheme also higher level of financial support is needed in order to encourage investments, but on the other hand the high-risk approach also gives producers incentives to make efficient use of the market, thus decreasing indirect costs. The conclusion is that the right design of support scheme depends on the level of current penetration of a renewable energy, the competitiveness of the respective market and the goal of the policy maker. If the purpose were to effectively introduce renewable energy to a market it would be appropriate to minimize their risks, but if the share of renewable energy is already higher it seems justified to burden new projects with more responsibility and costs. (Klessman et al. 2008)

5.4.2 Tradable green certificates

Tradable green certificates (TGC) are the opposite of the feed-in tariffs in a sense that policymakers control the amount of production and the price is left to the market to decide. In this system the environmental value of wind power is separated from the actual electricity, which is sold normally in the market. Producers are given tradable certificates relative to their production and the demand for these certificates comes from the electricity users or retailers who are obligated to supply a set percentage of the electricity from the renewable energy sources. Certificates can be traded either bilaterally or through auctions in a provided market place. TGCs are currently in use in Sweden (Åstrand and Neij 2006) and the UK (Klessman et al. 2008).

Theoretically the most notable advantage in TGC is its dynamic efficiency, which means that the system can be easily adapted to fit the changing circumstances by altering the size of the buying obligation (GreenStream Network Oy 2007). The flipside of the coin is that the price of the system to electricity users can turn out to be very high when the price is formed in the market. Furthermore, a TGC scheme leaves the actual electricity markets untouched since wind power producers sell their production in the markets just as all the others, which means that TGC suits open and competitive markets very well. To a wind power producer the disadvantage is that they have to navigate the uncertainties of two markets, since the prices of electricity and tradable certificates are continuously changing (Klessman et al. 2008).

A quota obligation corresponding to a TGC system was introduced in the UK in 2002 (2005 in Northern Ireland). The system requires electricity suppliers to supply an increasing share of electricity from renewable sources. The obligation is met by presenting Renewable Obligation Certificates (ROC), which are issued by the regulator Ofgem for all domestic renewable energy sources (Klessman et al. 2008). In the UK, the TGC system has not delivered the envisaged target of increasing the share of renewables to 5,5 % by 2005-2006. In reality, the share of renewable energies grew from 1,7 % in 1997 to only 4,1 % in 2005 (European

Commision 2006 cited by Klessman et al. 2008). The installed wind power capacity amounted to 3 330 MW in 2008 (British Wind Energy Association 2009). Although hasty conclusions should not be drawn based on experiences of only few years, it would seem that at least in the beginning the TGC system has not been as effective as was hoped for.

In Sweden the experiences of TGC scheme are not entirely positive either. The TGC system was established in Sweden in 2003 (Åstrand and Neij 2006), and the total installed wind capacity was approximately 570 MW at the end of 2006, showing only a very modest growth (Meyer 2007). According to Meyer (2007), the main reasons for failure were the lack of stable and long-range framework conditions. Also Åstrand and Neij (2004) have criticized Swedish wind energy policies about the lack of comprehensive long-term strategy and continuity. Based on the experiences in Sweden, one of the central problems in the TGC system is that the market for certificates does not function as desired (Long-Term Climate and Energy Strategy 2008). When volumes are small and there are only few sellers, the market is not truly competitive. This means that in a small market TGC system could not be used for wind power only but all renewable energies would need to be integrated. In addition, the international trade of certificates would greatly improve the functioning of the system (Long-Term Climate and Energy Strategy 2008). As discussed earlier, a common support scheme would, however, be politically very problematic as the new investments would occur in the country where the costs are the lowest.

5.5 Discussion on the optimal support scheme for Finland

The investment subsidy-based support scheme currently in place in Finland has only been able to prompt slow growth in wind power capacity compared to other European countries. In the future more rapid increase is needed in order to fill the EU obligations of increasing the share of renewable electricity to 33 % of total consumption. As already discussed, the choice of an instrument is not clear-cut. Besides pros and cons of each instrument, also the local conditions, current wind power penetration and policy markers' objectives affect what an optimal support scheme would be like.

In this chapter possible policy instruments are assessed mainly based on three criteria: effectiveness, cost efficiency and dynamic efficiency. Effectiveness refers to how fast growth in wind power capacity the instrument is able to prompt. Cost efficiency compares this effectiveness to the costs needed to achieve it. Thus it is possible that one instrument prompts fast growth in capacity and is thus highly effective, but also has very high costs resulting in a low cost-efficiency. Dynamic efficiency refers to the adaptability of the instrument. It tells how well the instrument can be adjusted to different circumstances, how well it can be modified based on experiences and how much incentives it gives to the producers to develop their operations further based on market signals.

Based on discussion above, TGCs can in practice be ruled out as a potential instrument in supporting wind power in Finland. Due to a small size of the Finnish markets the TGC scheme could not be used solely for wind power, but would at the very least require integration of all renewable energies into the same system. Even then the market for the certificates might suffer from a lack of competition, and the possibility to harmonize the support schemes with other countries in the Nordic market does not seem viable in near future. In addition, experiences from the UK and Sweden indicate that TGCs have not been very efficient in encouraging growth of the installed wind power capacity.

After ruling out TGCs, the most feasible alternatives for a support scheme are feed-in tariffs and investment subsidies. Since Finland is a part of the common Nordic market, it is clear that the support scheme must fit the open markets as well as be possible to avoid distortions in the competition. Feed-in tariffs as well as TGCs are often mentioned to be "market-based" instruments. This term usually refers to that under these schemes, private actors compete in carrying out new investments and either the price or the quantity of production is left to markets to decide. This ensures that all the actors in the market have the same incentives and the most cost-efficient projects are implemented first. However, the term "market-based" instruments can be criticized. It is not entirely clear that for example fixed feed-in tariffs suit the free markets any better than investment subsidies. The former actually isolates to a large extent wind power producers from the market, because they sell their production to a national TSO who has an obligation to buy it at a set price. The wind power producers have thus little incentives to react on signals from the market. In contrast to this, in investment subsidy based systems, once the capacity has been build wind power producers act on the markets the same way as all the other electricity producers facing the same risks. Also the resources are utilized effectively under an investment subsidy scheme, provided that the subsidies are granted as a percentage of investment costs so that the projects that were most profitable also without subsidies will be implemented first.

It is noteworthy that investment costs make up the largest share of total costs of wind power.

This raises a question whether it makes sense to support wind power by feed-in tariffs, which do not help to make the initial investment, but support the projects once they are already in the market and can cover operating costs by sales. Also a majority of electricity market stakeholders seem to be generally satisfied with the existing choice of instrument even though the level of subsides is deemed to be low (see e.g. GreenStream Network Oy 2007 and Varho 2006).

The fact that in Finland investment subsidies have not been as efficient in promoting growth in wind power capacity as they were hoped can be rather caused by the design and implementation of the system than the instrument itself. The most significant problems in the current system have been too low levels of subsidies, poor suitability for large projects and uncertainty that is mainly caused by the insufficiency of budgeted funds for each year. All of these problems are in practice easy to solve by raising the level of the subsidy and directing more funds to the system. Greenstream Network Oy (2007) has estimated that in order to increase installed wind power capacity to 2 000 MW by 2020, the level of investment subsidy should be around 50 % of total investment costs for onshore wind power and 45 % for offshore projects. The problem of continuity could be solved e.g. by establishing a fund where the subsidies would be paid so that the budgeted funds for each year would not constrain the granting of funds. All this would, however, mean substantial increase in costs to the government, which can make it politically a very difficult decision.

If the effectiveness has been the most severe drawback of the investment subsidies, for feed-in tariffs it is probably the most significant advantage. They have proved to be able to substantially accelerate growth in the wind power production in many countries and are generally deemed to be a very effective instrument (Greenstream Network Oy 2007). However, their perhaps greatest disadvantage is poor dynamic efficiency. As discussed earlier, feed-in tariffs isolate wind power producers from the market either completely (if tariffs are fixed) or to some extend (if tariffs are a premium on top of market price). This means that they do not have very strong incentives to react on signals from the market. Also, even though it is possible to set feed-in tariffs differently depending on e.g. the age and location (on- or offshore) of the project, it is not possible to make changes in the system during guaranteed support periods even though the circumstances can change significantly in 7 to 20 years. This means that if the initial tariff level is set badly, there is no opportunity to correct it afterwards. When this is combined with the fact that in order to prompt new investments the tariffs must be set rather slightly too high than low, there is a risk that the costs rise very high. High costs, in turn, easily lead to a weak cost-efficiency of the system (Greenstream Network Oy 2007).

In investment subsidies the dynamic efficiency is significantly better. The level of subsidy and the criteria projects must meet to get funding can be easily changed if the circumstances change. At the same time, this can be a drawback as well, because the possibility to quick changes in the system adds uncertainty to project planning and stresses the importance of persistent and convincing policy. In addition, a related disadvantage in investment subsidies is that the level of bureaucracy is rather high due to handling of the applications and monitoring of the projects in order to pay the subsidies based on materialized costs. The administrative costs are considerably higher in investment subsidy-based systems than in feed-in tariffs. However, removing the discretionarity of the subsidies and granting them at a certain level to all projects that fill pre-set requirements can reduce both administrative costs and uncertainty to investors. In this case the dynamic efficiency naturally suffers, so the challenge is to find a balance between simplicity and dynamic efficiency.

The cost-efficiency of the investment subsidies is also in principle good since the subsidy level can be adapted to each project. If the official who decides the level of subsidy had complete information it would, in principle, be possible to set the subsidy on the exact right level so that the project would be implemented but the support costs would be as low as possible. In practice officials' information is not perfect, but it is reasonable to assume that their estimates are rather good since they have an access to information about materialized costs of earlier projects. Thus the cost-efficiency of investment subsidies is in general good.

The cost structures of feed-in tariffs and investment subsidy schemes are rather different. Investment subsidies require high costs at once when new projects are started. In feed-in tariffs the costs come more steadily over time. In investment subsidies also the interpretation of the costs is more straightforward as they consist of the administrative costs and the actual subsidies paid. In the feed-in tariff scheme the actual costs are the difference between the tariff and the market price of electricity. This makes it difficult to estimate the costs of feed-in tariffs in advance because there is plenty of uncertainty in electricity prices.

In the report to Finnish Energy Industries (ET) GreenStream Network Oy has estimated the costs of increasing the installed wind power capacity to 2 000 MW by 2020 using feed-in tariffs and the current investment subsidy-based scheme[7], where the level of subsidies has been raised to a level needed to meet the target. For onshore projects this means an investment subsidy of around 50 % and to offshore projects 45 % of total investment costs. Also the cumulative costs in 2039 are counted to depict all the costs from the instrument that are needed to gain increase of 2000 MW by 2020. 2039 is the year when the last projects granted feed-in tariffs for 20 years drop off from the system. These costs will be discussed in more detail in chapter 6.3, here more attention will be paid to the structure and relative size of costs than the actual figures. Figure 5-3 represents the cumulative costs from invest subsidy-based and feed-in tariff schemes. The cumulative costs by 2020 are the highest for fixed feed-in tariffs that are guaranteed for 10 years and the lowest for the 20-year feed-in tariffs. However, when looking at the long-term costs (cumulative costs in 2039), the costs of both feed-in tariffs schemes are substantially higher than investment subsidies. The development of costs in different support schemes is very different as well. Since investment subsidies are only paid once to each project, the costs from an investment subsidy –based system would be rather stable over years. In feed-in tariffs the stock of projects to which subsidies are paid increases constantly, and so do the cost.

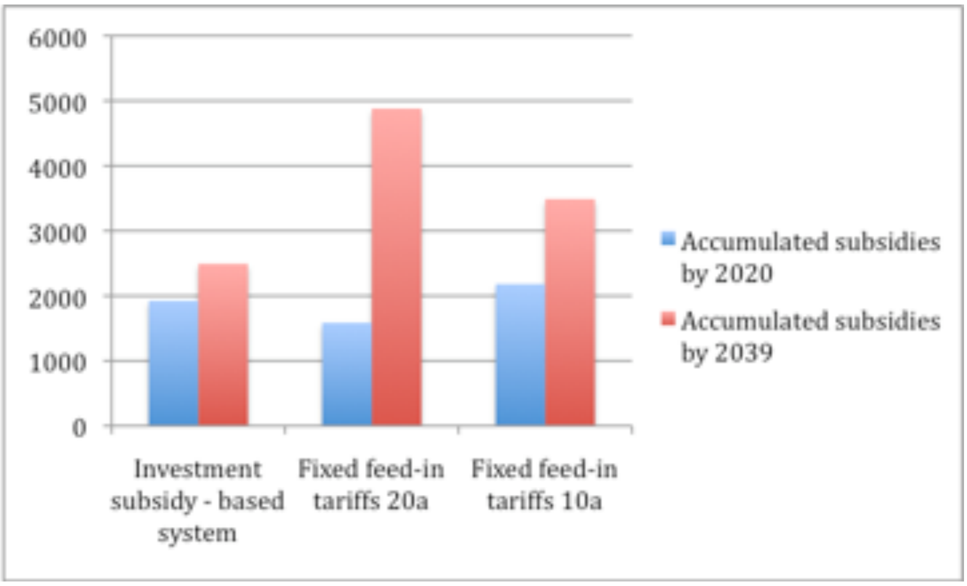

Figure 5-3. The cumulative costs (Million euros) from public support under different support schemes. Source: Greenstream Network Oy (2007)

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[7] Some most central assumptions are that the spot price of electricity will be 45 €/MWh and the price of EU ETS allowance 20 €/MWh.

An important difference between the costs of these two instruments is that in investment subsidies government can easily control the costs, but in feed-in tariffs they are locked in for many years and must be paid whether the circumstances remain the same or not. For example Denmark had to abandon a fixed feed-in tariff scheme due to high and rapidly growing costs in 1990s (GreenStream Network Oy 2007). It is, however, noteworthy that very high costs are associated with the phase when wind power penetration has grown very fast and it has more than just a marginal role in total production. Since the current share of wind power in the Finnish production mix is only a negligible 0,2 % (Statistics Finland 2008), the problem of soaring costs would not be topical in the near future. However, it is also notable that in Nordic markets the electricity prices are lower than in e.g. central Europe, which increases the costs from support to renewable energies. This is based on the fact that the subsidies needed equal the difference between the price of electricity and the production costs. If the price is high, less support is needed to make wind power cost-competitive.

Apart from the level of costs, it is also an important question how these costs will be covered. It should be pointed out that theoretically the financing of the system is a separate question from the choice of the instrument. In theory any instruments could be financed from the government budget or by gathering additional fees from electricity users. In practice, the financing has usually been organized through the existing institutions: investment subsidies from the budget and feed-in tariffs by fees from electricity uses. From the point of view of the economy as a whole, this question is irrelevant since the costs are the same independent of whether the funds come from the government budget or directly from the consumers. The difference is in the burden sharing: if the funds come from the budget all tax payers contribute to the system, but in feed-in tariff system the electricity users are paying the costs. The former benefits heavy users of electricity such as energy intensive manufacturing and house owners with electricity heating while the latter benefits everyone who consumes electricity economically. Thus feed-in tariffs normally give clearer incentives to electricity saving since the users pay the costs directly.

The advantages and disadvantages of feed-in tariffs and investment subsidies are gathered in table 5-1. Based on the discussion above, there seems to be a trade-off between effectiveness and cost-efficiency. Deciding which support system is better thus depends on the criteria. If the most important goal is to rapidly increase investments in wind power, this could be best achieved by feed-in tariffs. This might indeed be the case in Finland, since in order to fulfill

EU requirements of increasing the share of renewable electricity to 33 % of total consumption by 2020 a dramatic growth in wind power investments is needed (GreenStream Network Oy 2007). When using feed-in tariffs this growth will, however, come at a potentially high cost. In the long run a more cost-efficient way to increase wind power production would be to develop the current investment subsidy-based system further.

Finally it should be pointed out that the arguments for and against each instrument here refer to a "school book" example of them. In practice the final design and details of the system to a large extent determine its effectiveness and cost-efficiency. Also e.g. land-use planning has a great impact on providing positive circumstances for investors. Neither of these instruments can work effectively if wind power is not given consideration in land-use planning.

Table 5-1. Summary of pros and cons of investment subsidies and feed-in tariffs.

	Feed-in tariffs	Investment subsidies
Suitability to free markets	In premium tariffs good, in fixed tariffs the isolation of wind power producers from the spot market can be problematic	Good
Level of bureaucracy	Moderate	High
Burden sharing typically*	Electricity users	All taxpayers
Political suitability**	Politically easier	Politically difficult
Costs	In the long run higher than in investment subsidies. Low at the beginning but rise fast. Locked in for many years per project.	In the long run lower than in feed-in tariffs. More stable over time and easier to control
Effectiveness	Good	Currently very modest, potentially good depending on the level of subsidy
Dynamic efficiency	Low	Good
Cost-efficiency	Ambiguous, potentially low if the level of tariffs is set badly	Good

* Theoretically the financing of the support scheme is a separate question from the choice of the instrument. All the instruments can be financed in numerous ways including taxes and additional fees to electricity users. In practice the financing is, however, usually handled through the existing institutions.

**This represent the difficulty of substantially raising budgeted funds. However, in principle the financing can be organized also differently, see *

6 Impacts of large-scale wind power production

In this chapter the impacts of large-scale use of wind power on the Finnish electricity markets will be studied paying attention to emission reductions, landscape and noise damages close to wind farms and especially the functioning of the Nord Pool market. In addition, the public support costs needed to achieve this increase will be analyzed.

It is clear that the impacts wind power will have on electricity markets depend on the level of penetration. As wind power currently makes up only 0,2 % of total electricity market, Finland starts from a situation where it has only a very minor role. Hence also the effect of wind power on the functioning of the Nord Pool market is currently small and for example landscape impacts and noise are only problems in some rare locations. However, the objective stated in the Long-Term Climate and Energy Strategy (2008) is to increase installed wind power capacity from around 110 MW in 2007 to 2 000 MW by 2020. This would mean a dramatic growth in installed capacity, which would also change the nature and magnitude of impacts when moving towards year 2020.

It should also be mentioned that there are many sources of uncertainty that make assessment of the impacts difficult. It is certain that e.g. the world price of oil, integration of the Nordic electricity markets to the central European and international agreements and other political decisions can also have a great impact on how wind power forms electricity markets in the future.

6.1 CO_2 Emissions

The most central motivation for increasing the use of wind power is probably environmental concerns. In order to tackle climate change especially CO_2 emissions need to be cut. In addition, wind power can help to reduce SO_2 and NO_X emissions, which have more local impacts. Wind power reduces emissions by replacing other existing energy sources. This is due to the merit order; as marginal costs of wind power are practically zero, it is kept running whenever wind is available. This supersedes other electricity generation forms possessing higher marginal costs.

Naturally also wind power causes some emissions when the turbines are manufactured, transported to the site and finally disposed. According to Holttinen (2004), these CO_2 emissions are of the order of 10 g CO_2/kWh. Martinez et al. (2009) have estimated the life cycle environmental impacts of a multi-megawatt wind turbine. They discovered that the payback time for the contamination caused by wind power plant is 221,9 days, which is less than 3,1 % of a 20-year lifetime (Martinez et al. 2009). This of course depends on the site where turbine is established and how turbine parts are recycled after decommission, but in any case the emissions are negligible compared to electricity generation forms utilizing fossil fuels. In this study the CO2 emissions from wind power are assumed to be 0, since the analysis is focused on comparing emissions between different energy sources and the construction of any power plants causes some emissions. There is no reason to expect emissions from establishing a wind farm to be significantly larger than other power plants.

The amount of CO_2 that will be abated depends on the production modes replaced by wind power. In the case of Finland and the Nordic markets, wind power will replace production in condensing power, mostly in coal fired plants, resulting in a reduction of 620-700 gCO_2/kWh wind power produced (Holttinen 2004). This means that if the wind power production were approximately 6 TWh in 2020 as would be the case if the installed capacity was 2 000 MW, the amount of yearly abatement would be near 3,7 to 4,2 Mt of CO_2. In 2006 total Finnish greenhouse gas emissions were 80,9 Mt CO_2, and it is estimated that they will grow to 88 Mt CO_2 by 2020 if no further changes are made to constrain them (Long-Term Climate and Energy Strategy 2008). This means that 6 TWh of wind power production would decrease CO_2 emissions by around 4,2-4,8 % in 2020.

If the wind power penetration were to increase dramatically in the future resulting in a situation where there would be no more coal to be replaced, wind power would replace other condensing power capacity, most likely natural gas combines-cycle (NGCC). This would result in an abatement of about 300 gCO_2/kWh due to a high efficiency of NGCC and other changes in the energy system (Holttinen 2004). Since the share of condensing power in the Finnish production mix is 18 % and coal is used as a fuel in around 64 % of the production (Statistics Finland 2008), the former case where wind power replaces coal-fired condensing power plants will apply for a very long time. Even if wind power capacity were to increase to the government's objective of 2 000 MW by 2020, wind power would only make up around 6 % of the total supply in Finland, which is substantially lower than the share of approximately 11 % of coal-fired condensing power.

As mentioned in the previous chapter, energy sector is participating in the EU ETS. Thus CO_2 emission reductions have a positive opportunity cost: if a company does not need all the emission allowances granted, they can be sold in the market. One way to assess the economic value of the CO_2 abatement is thus to use the price of emission allowances (EUA). If the price would remain at the spring 2009 level, at approximately 15 €/tCO_2 (Vertis Zrt. 2006), the value of the emissions reduced yearly because of wind power would range from 55,5 to 63 billion euros.

There are, however, at least two limitations to this approach. Firstly, there are no final decisions yet on what will happen after the end of the second period of EU ETS in 2012, so it is extremely difficult to estimate the future price of the EUAs. Examples of economic value of emission reductions at different price levels are illustrated in table 6-1. Secondly, not all emission reductions will necessarily take place in Finland. Because of the common Nordic market, capacity is replaced in locations where it is currently most expensive. It seems that the production replaced by the increasing Finnish wind power capacity will be mostly located in Finland and Denmark due to large share of hydropower in Sweden and Norway. Limitations in the transmission capacity and Finland making up a pricing area on its own increase the share of impacts that take place in Finland. From an environmental perspective this is of course irrelevant, as reductions in CO_2 emissions have a global effect despite the country they take place in. However, if wind power is subsidized in Finland, Finnish taxpayers might end up supporting energy companies in Denmark, as well.

Despite these limitations, the presented figures suggest that also the economic value of the emission reductions is considerable. The relative size of them compared to costs from wind power will be discussed further in chapter 6.5.

Table 6-1. Economic value of the CO2 abatement.

	Price of EUA				
Yearly CO_2 abatement (Mt)	5 €	10 €	15 €	20 €	40 €
3 700 000	18 500 000	37 000 000	55 500 000	74 000 000	148 000 000
4 200 000	21 000 000	42 000 000	63 000 000	84 000 000	168 000 000

6.2 Aural and visual impacts

Even though the public usually has a positive attitude towards renewable energy in general, having a wind farm close to one's own home is sometimes seen quite differently. Especially in countries where wind power has a fair share of electricity production and there are numerous wind farms, concerns have risen about the impacts that aural and visual presence of wind turbines could have on local communities, especially surrounding property values. Measuring these potential harms is, however, difficult. What would be the right price for the visual harm that wind turbines cause for a summer cottage landscape? Or for the noise that can be heard on one's backyard?

There is a wide range of methodology that can be used to measure these impacts from different kinds of opinion surveys to *contingent valuation* and *hedonic pricing method*. However, none of the methods seem entirely unproblematic. Opinion surveys do measure perceived harms, but the answers can be biased and overestimate the real damage on e.g. property values. Contingent valuation method means interviewing people and asking how much they would be willing to pay in order to get the factor causing harm removed. The difficulty in this method is that people know that they do not actually need to pay, which can make them overstate the impacts. In addition, people also have different financial situations and thus the estimations of people with less financial resources can be lower than the estimations of wealthier residents, even thought this would not reflect the extend of perceived harm. Hedonic pricing method refers to comparing price of houses located close to a windmill with houses that are further away from wind farms. This is a challenging methodology from the point of view of the data, since in order to get correct estimates using statistical methods there should be data from rather many transactions. In addition, there are numerous factors affecting housing prices and hence ensuring that *ceteris paribus* holds is difficult.

Even though there are problems with all the methods, research utilizing them can, nevertheless, give some indication of the direction and extent of the impacts. Sims et al. (2008) have studied the impact of wind farms on housing prices in the United Kingdom. First, they introduce earlier research based mainly on opinion surveys and point out that based on the surveys the impact of windmills is ambiguous. Many of the research findings show none or little evidence of the adverse impacts and in some studies the impact would even seem to be positive. Sims et al. (2008) are thus aiming at improving existing research by executing their own study based on a hedonic pricing method. The study is focusing on properties within one mile of the Bears Down wind farm in southern England as this was the only place in the UK where a sufficient number of sales transactions have been made within close proximity to the wind farm. No relationship is observed between the number of wind turbines visible and reduction in value, nor is there any significant evidence to suggest a relationship between distance to the wind farm and house price. Thus the study finds no evidence to suggest that wind farms reduce property prices. However, the authors point out that one reason for this could be that in the wind farm featured in the study the wind turbine height, which was approximately 60 meters, is relatively small compared to modern turbine heights of 100 meters or even above. (Sims et al. 2008)

Moran and Sherrington (2007) have used cost-benefit analysis to assess the economic feasibility of a large-scale wind farm project in Scotland while taking into account negative and positive externalities of generation. They use existing *willingness to pay* (WTP) value information and transfer and calibrate it to fit the situation in question. In this case, contingent valuation method is used to assess the damage that wind farms cause to the user value of landscape. This refers to the value that landscape has for its users, that is, residents and visitors who see it. It is found that the combined welfare loss of residents and visitors due to visual disamenity was £567 000 per year, which approximately corresponds to €387 000[8]. In the study also the so-called non-user disamenity was estimated. This refers to the assumption that, beyond local impacts, wider population of the UK might have preferences over the impacts of wind farms, irrespective of whether they actually experience them directly. Since measuring the non-use value of landscape is even harder than use value, Moran and Sherrington (2007) end up using a value of £40,74 million corresponding to €27,78 million, which they get by multiplying the number of Scottish households by annual welfare loss of £19,4 pounds per household estimated earlier by Bergmann et al (2007). However, the authors themselves point out that this estimate raises numerous questions about the concepts of non-user value and therefore use it only as a rough estimate to see how it would affect the net present value of the wind farm project. (Moran and Sherrington 2007)

Also Munksgaard and Larsen (1998) have studied the question of to what extend is it possible to monetize external effects of wind power. The scope of their study is Denmark and aural

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[8] Using the average UK pound sterling/euro exchange rate 0,6818 in 2006.

and visual effects are assessed through interviews of households living near wind farms. It is found that out of 77 % of households interviewed that heard noise from the windmills, 86 % were not disturbed by the noise inside the house and 63 % were not disturbed outside the house. The rest were either slightly or strongly disturbed by the noise. In regard to visual effects a majority of households interviewed, 71 %, found that windmills fit well in to the landscape while 17 % thought that it disfigured the landscape and 2 % found that the windmills were decorative. After applying contingent valuation it was discovered was discovered that an average payment per windmill that respondents would have been willing to pay in order to get them removed was $26 per year, corresponding to 0,006 cents per kWh. Since contingent valuation has its drawbacks, Munksgaard and Larsen (1998) attempted to check the results by applying hedonic pricing on the same locations. They found that if the costs are divided to generated electricity, hedonic pricing gives costs of 0,17 cents per kWh, substantially more than contingent valuation. Since the sample is small, only 72 transactions, some of the results are insignificant, but authors conclude that they would seem to rather weaken than confirm the assumption that contingent valuation overestimates the impacts. It is, however, problematic to compare figures acquired through these two methods. Aural and visual impacts cause harm year after year as long as respondent is living close to a wind farm, whereas impact from decreased price of property usually only concerns a household once the house is sold.

Based on these experiences from other countries, it is reasonable to assume that growth in wind power capacity would increasingly cause visual and aural damage also in Finland. Most of the potential wind power sites in Finland are in offshore locations. In practice this means building on the coastal areas. In most cases wind turbines would probably not be built beyond visible horizon as this would be much more expensive than building on the shallow waters near the coastline. This means that most of the visual and aural impacts will take place in the same locations that are widely used for recreational purposes. At the same time, Finland is rather scarcely populated and also on the coastal areas the impacts will directly harm rather small group of people. The aspired capacity growth to 2 000 MW by 2020 would, however, mean a remarkable increase in the number of wind farms in Finland, and even if this objective would not be reached completely, the visual and aural impairments would increase rapidly. This would presumably also raise local people’s resistance towards new wind farms.

Quantifying the aural and visual impacts is difficult, but based on the studies from other countries introduced above, the harm could vary from average of few to several tens of euros per resident or visitor per year. Finnish research is needed to discover more accurate figures. In addition to this there is also a question of non-user value, which would incorporate the value of landscapes to other Finns that do not experience the harm from turbines themselves. This aspect, however, is excluded from the study and it is only concluded that it is possible that the visual and aural impacts are more significant than what is estimated by considering the user-value only.

6.3 Public support costs

As discussed in chapter 5, public support is needed in order to substantially increase wind power capacity in Finland. This means that one central outcome from the large-scale wind power production will be the costs from public support that need to be covered for example by collecting more taxes or adding an extra fee to electricity bills. In Finland GreenStream Network Oy (2007) has investigated the level of support needed to increase the installed wind power capacity to 2 000 MW by 2020 in the survey for the Finnish Energy Industries. In the survey it is estimated that the level of support needed to reach this target, regardless of the way it is delivered, would be average of 40 €/MWh for onshore and 37 €/MWh for offshore projects in the period of 2008-2020. In this scenario it is assumed that the prices for CO_2 certificates is 20 €. As prices of these certificates strongly impact electricity prices and thus competitiveness of wind power, the support needs have been calculated also for scenarios where CO_2 certificates cost 5 € and 40 €. Table 6-2 shows the results. The reason for lower support level needed for offshore wind power is that even if their investment costs are higher, most of the potential sites in Finland are in offshore locations. This means that on average, offshore power plants are presumed to become bigger and more profitable than onshore projects.

Table 6-2. The level of support (€/MWh) needed for increasing the installed wind power capacity to 2 000 MW by 2020. Source: GreenStream Network Oy (2007)

Building year	Onshore			Offshore		
	5€	20€	40€	5€	20€	40€
2010	52	42	29	50	40	27
2020	47	37	24	44	34	21
2008-2020 average	50	40	27	47	37	24

The different profiles of the paid subsidies depending on the policy instrument were already discussed in chapter 5.5. Figure 6-1 represents the development of costs in feed-in tariff and investment subsidy-based support schemes estimated by GreenStream Network Oy (2007). It can be seen that the costs from feed-in tariffs exceed the costs from investment subsidies in 2017 for the scheme where tariffs are guaranteed for 20 years and in 2014 for the scheme where tariffs are guaranteed for 10 years.

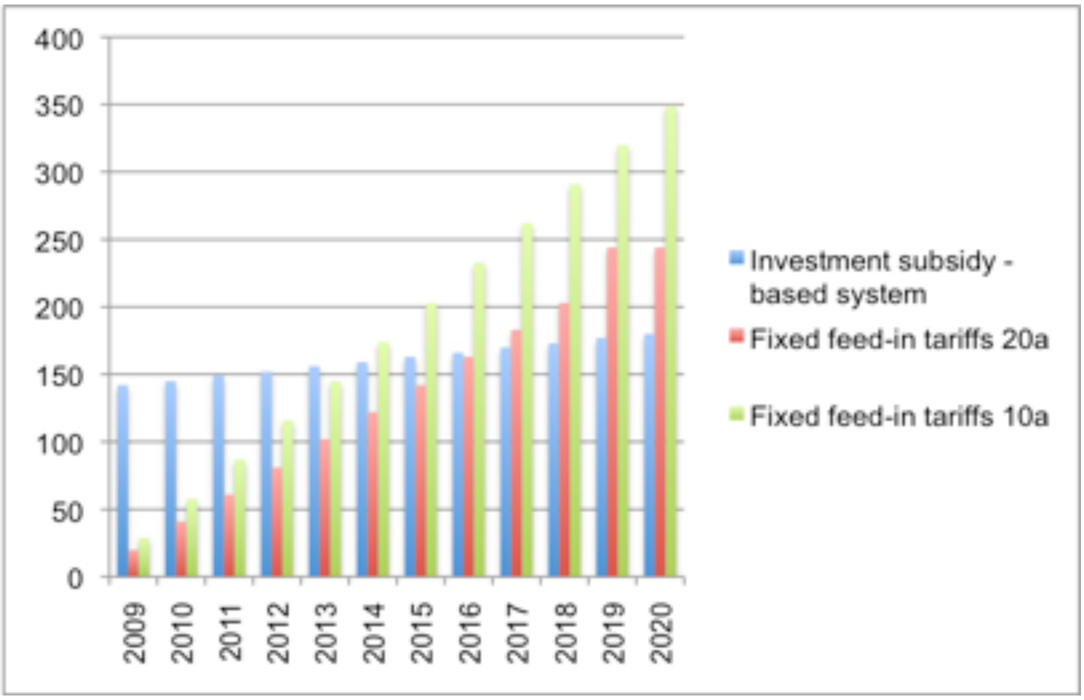

Figure 6-1. Subsidies (million euros) for wind power under investment subsidy – based scheme and feed-in tariffs. Source: Greenstream Network Oy (2007)

The cumulative subsidies from investment subsidy-based and feed-in tariff schemes are represented in table 6-2. It should be pointed out that these estimates made by GreenStream Network Oy (2007) possess some serious limitations. Firstly, unlike in these calculations, the need to increase wind power production would most likely not end in 2020 when the objective of 2 000 MW is reached, but further investments would be needed after that. Secondly, the figures are only calculated for one assumed electricity price (45 €/MWh) and EUA price (20 €/MWh). There is, however, a great deal of uncertainty in these assumptions, especially in the long run, and it is possible that the estimates strongly over- or underestimate the real costs. The higher the prices for both electricity and emissions trading allowances are, the lower the cost from support to wind power and vice versa. Finally, the cost estimates from different years have not been discounted in any way, so it can be rightly questioned whether it makes sense to directly summarize subsidies from years 2009, 2019 and 2039. For this reason also cumulative subsidies of discounted future values until 2020 are calculated in table 6-3. Unfortunately, the discounted figures could not be calculated for year 2039 because the necessary data was not provided in the report.

Table 6-3. The cumulative subsidies needed for increasing installed wind power capacity to 2 000 MW by 2020. Source: (non-discounted figures) Greenstream Network Oy (2007)

Cumulative subsidies, Million euros	by 2020				by 2039
	No discounting	i=0,01	i=0,03	i=0,05	No discounting
Investment subsidy - based system	1924	1825	1638	1480	2492
Fixed feed-in tariffs 20a	1586	1493	1297	1133	4880
Fixed feed-in tariffs 10a	2180	2108	1832	1601	3488

Despite all the limitations, these figures can give a rough estimate of the magnitude of the costs from public support and how they develop under different support schemes. These calculations suggest that by 2020 the cumulative costs of the support needed to reach the installed capacity of 2 000 MW would be the magnitude of around 1,6 to over 2 billion euros. If the subsidies from coming years are discounted, the cumulative subsidies naturally drop. With a discount factor i = 0,03 they could range between 1,3 and 1,8 billion euros. When looking at the figures for 2039 when all the costs from reaching the goal of 2 000 MWs have materialized, the lowest cumulative costs are obtained by the investment subsidy-based system. Thus the calculations indicate that in the long run feed-in tariffs are a more expensive support instrument than investment subsidy based ones. This would be intuitive in a sense that when the support is given as an investment subsidy, investors have to pay less interest from the funding of the project than when they get the public support gradually over years as in feed-in tariff schemes.

6.4 Functioning of the market

The Nordic electricity market was introduced at the beginning of this study. In this chapter are discussed the impacts of large-scale wind power production on its functioning, more precisely on spot prices, balancing power and transmission capacity needs and finally the competition in the market.

When assessing impacts in this chapter it will be presumed that no changes will happen in the central market institutions and that wind power has to adapt to the prevalent conditions and rules. It is, however, noteworthy that the current electricity market institutions, including e.g. balancing requirements and the Nord Pool trading mechanisms, have formed gradually in the past. They have been shaped by security of supply aspects, politics and most importantly the most dominate production forms: condensing power and CHP utilizing fossil fuels, hydropower and nuclear power. All these generation forms share some common attributes: their production is rather centralized, and can be easily controlled each hour. In contrast, wind power is intermittent and characterized by distributed generation even though the size of wind farms has been growing. This means that some current structures of the electricity market can be problematic from the wind power point of view. An example of this is the trading system in the Elspot, where the market is cleared 12-36 hours before the actual delivery. Compared to a case where the time scale from bids to delivery would be shorter, the design of this trading mechanism causes forecasting difficulties and extra costs to intermittent production forms such as wind power. In the times when increase of wind power production is supported by subsidies one can question whether it is reasonable to retain the market mechanism that forms a barrier to intermittent production forms or whether some changes should be considered in order to take their needs into account.

6.4.1 Spot prices

Due to price formation process in Nord Pool, an increase of wind power capacity also has an effect on the spot prices of electricity. As already mentioned, the marginal costs of wind-generated electricity are negligible. This means that in the Elspot market the supply curve shifts to the right in conjunction with the amount of a wind power bid at each hour. The demand and supply curves will then cross at the point where the price is either the same or lower as without wind power. The former happens when the amount of wind power is smaller than the production form on the margin. Respectively, the price is lower when there is enough wind power to supersede the production form on the margin and thus bring the price to the level of the marginal costs of the next most expensive production form. Figure 6-2 illustrates a simplified example of the impact of wind power on the price formation in Elspot. The upper picture represents a situation where there is a negligible amount of wind power, the lower a situation where there is a bigger wind power capacity in the market.

Naturally is Finland only one part of the Nordic market, and thus changes in the Finnish production capacity do not have as big impacts as if the capacity would increase respectively

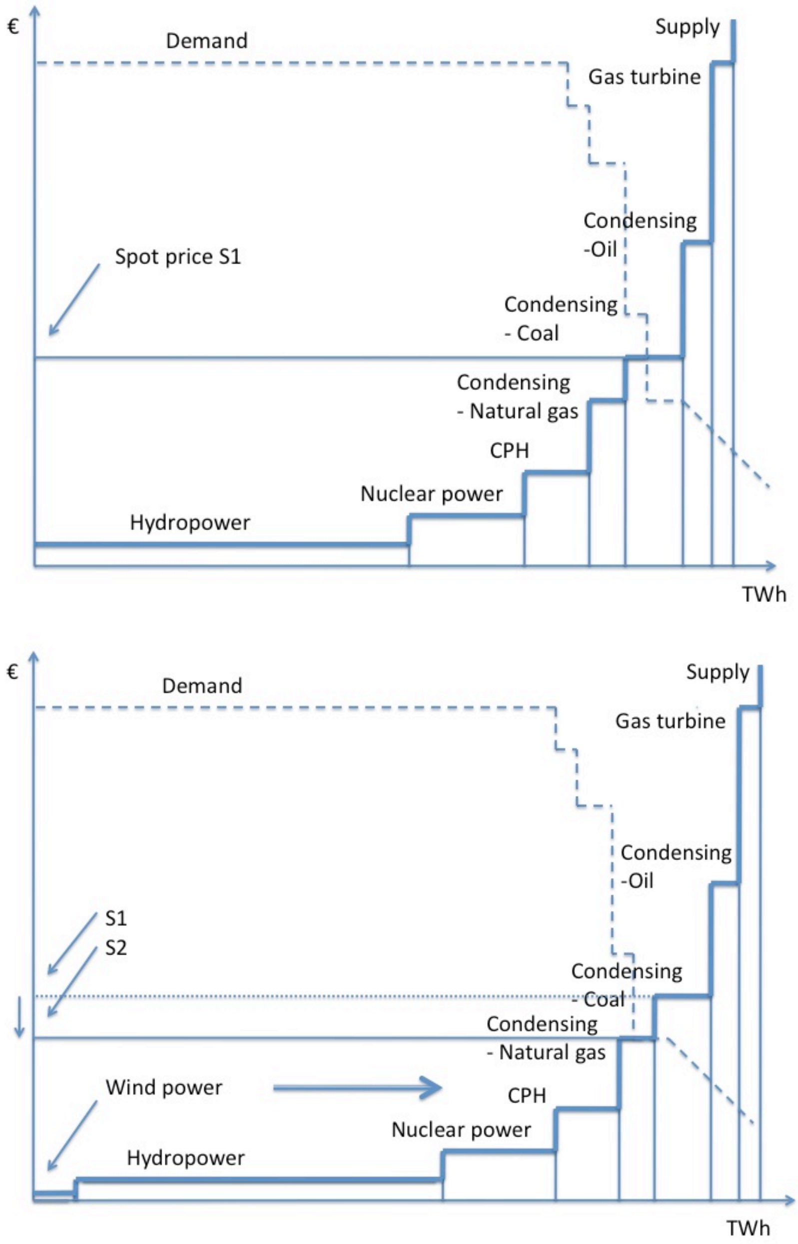

Figure 6-2. An example of the impact of wind power on the price formation in Elspot

also in other parts of the market. Impacts of large-scale wind power production on spot prices in the Nordic market have been studied by Holttinen (2004). Using simulations it has been found that adding a significant amount of wind power to the Nordic market would decrease the average spot price by 2 €/MWh for each 10 TWh/a wind-generated electricity added. In this scenario wind power is added to the market as an extra power, that is, no capacity is replaced by it. In another, perhaps more realistic long-term scenario, the amount of thermal (condensing power) capacity is decreased while wind power is added in order to demonstrate the replacement effect. In this case the impact on spot price is much more moderate, only 2

€/MWh for each 40 TWh added. Therefore, if the Finnish wind power production in 2020 would be around 6 TWh, the impact of the Finnish wind power capacity on the Nord Pool spot prices would be around 0,3 – 1,2 €/MWh depending on whether it is postulated that other capacity will be reduced due to wind power.

There is also some research available on the materialized impacts of wind power to electricity prices, conducted mostly abroad. In Denmark the share of wind power is larger than in other member countries of Nord Pool, and the effect of wind power on the consumer prices there has been investigated by Munksgaard and Morthorst (2008). Since congestions in transmission capacity cause the Nordic area to split into price areas every now and then, wind-generated electricity has the most significant impact in prices near to its location. Indeed, in Denmark it was found that wind power has the most notable effect on spot prices in periods with high wind speed and in areas suffering from congestions in the transmission capacity (Munksgaard and Morthorst 2008). According to calculations of Munksgaard and Morshorst (2008), the electricity retail price[9] would have been approximately 0,001 €/kWh higher in 2004, 0,004 €/kWh higher in 2005 and 0,0025 €/kWh higher in 2006 if wind power had been absent. Thus it seems that Danish consumers benefit from congestions in transmission capacity seeing that in periods with high wind power generation they lead to lower electricity prices in Denmark than in other parts of the Nordic market (Munksgaard and Morthorst 2008).

Klessman et al. (2008) have investigated the interaction between renewable energy support policies and electricity market design in Germany, Spain and the UK. In case of Germany Klessman et al. (2008) refer to a study by Neubarth et al. (2008), where it was found that spot-market prices at the European Energy Exchange in Germany were lower than average on days wind power feed-in was predicted to be high. Neubarth et al. (2008) discovered a price reduction of 1,89 €/MWh for every 1000 MW forecasted wind power. During a research period of 12 moths, an overall spot market price reduction was estimated 2,7 €/MWh (Neubarth et al. 2008). In Spain wind power has had a decreasing impact on spot prices in order of 2-3 €/MWh for every 1 000 MW of wind power in the market. In periods with very high wind the feed-in the price decrease was already approximately 20 €/MWh (Klessmann

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[9] Excluding transmission and distribution tariffs, taxes and VAT.

et al. 2008). There was unfortunately no data available from the UK on the influence of wind power on electricity prices. The results from different markets are not fully comparable, but they indicate that in different countries wind power has indeed had a lowering impact on electricity prices as the theory suggests. They also show that available transmission capacity and other local circumstances can have a significant impact on where and to what extend the price reduction materializes.

The impacts of electricity spot market price reduction are twofold. Consumers naturally benefit from lower prices. Even though lower price should in principle lead to more consumption, due to inelasticity of the demand it is unlikely that this small reduction in price would significantly increase consumption. This is the case at least in the short-term. For all electricity producers reduction in prices means lower returns. For some companies relying on fossil fuels this might be a crucial reduction of income, which may lead to an exit from the market. Using less fossil fuel operated power capacity leads to less CO_2 emissions, but can also have an unwanted effect. If too much capacity is removed from the market due to unprofitability, can this cause problems in extremely dry years when adequacy of supply can become an issue (Holttinen 2004).

6.4.2 Transmission capacity

Wind power introduces new challenges also for the transmission network. Due to the crucial role of wind resources, wind farms are often located in areas where the local consumption is low and the excess electricity has to be exported. In general, the grid networks were designed to fit the needs of power transmission from large, central (oil, coal or nuclear) power plants. This can be slightly problematic from a wind power point of view, since it would often require grid reinforcements in remote areas and also because the determination of needed transmission capacity is different from more conventional energy forms due to stochastic nature of wind (Georgilakis 2008). For wind power to have an opportunity to grow rapidly, special attention should be paid in the transmission planning, both nationally and, in the case of Nordic market, also across national borders.

In Finland most of the current wind power capacity is located on the coastal areas, and most of the future potential is in offshore locations. Fortunately the Finnish coast is rather well covered by the national main grid (Kara 2004), but local grids are naturally needed to connect new wind farms to it. The building of this connection to the closest national grid is the responsibility of the new power plant project. In general, the TSO Fingrid Oyj controls the transmission capacity. It also makes decisions on and covers the costs of grid reinforcements that may be needed if a big power plant connects to a grid in an area where there is not enough capacity to handle new production. This is not the case everywhere; for example in Spain and in the UK the new power plants project has to cover a part of the reinforcement costs, which means more costs for the investors as well as uncertainty about the size of payments (Klessmann et al. 2008).

According to the Long-Term Climate and Energy Strategy (2008), increasing the installed wind power capacity to 2 000 MW would require reinforcement of national main grid and increase in the transmission capacity between Finland and Sweden by one new connection in the northern parts of the countries. The geographical spreading of new wind power would greatly help in settling the transmission needs. These results are preliminary, but give presumably the right indication that some grid reinforcements are needed if wind power capacity increases significantly. This is rather intuitive, since wind power is more variable than conventional energy forms and thus raises the need for more transmission between areas depending on the windiness of different locations.

Unfortunately, there are no figures available about the expected costs of grid reinforcements that are needed to increase wind power production. It is also a problematic question whether all of these costs should be counted when estimating costs from wind power. The fact that wind power is the “last drop” that makes the capacity of transmission grid undersized does not mean that other production does not contribute to the need to reinforce the grids. On the other hand, it can be claimed that without wind power these costs would not be topical at the moment.

6.4.3 Balancing power

As already mentioned, one of the largest problems of wind power from the power system point of view is that it is variable and hard to predict in advance. Holttinen (2004) has studied the impacts of large-scale wind power production on the power system. According to the study, maximum hourly step changes in Finland are inside ± 20 % of the installed capacity. Changes are between ± 10 % of installed capacity 99 % of the time. The maximum 4-hour-variation is ± 40 % and 12-hour-variation 70 % of installed capacity. For large-scale wind power where one turbine makes up only a small share of total production, production variations are mainly caused by wind variability, not the stops and starts of individual power plants. Only in extreme weather conditions it is possible that all the turbines must be shut down from full power in order to protect the components. This is very unlikely since it is not realistic to presume that large-scale wind power would materialize in a geographically concentrated way when all the turbines would be prone to same weather conditions simultaneously. Correlation of hourly wind power production is over 0,7 for distances of less than 100 km and becomes weak (below 0,5) with distances above 200-500 km. Even a geographically well-dispersed wind power nevertheless has wide production range compared to other production forms (Holttinen 2004).

Large variations in production imply new requirements to power systems. In Finland all the producers are responsible for balancing their production, or have to make a contract with or sell their production to a balancing responsible operator. Balancing obligation means that if a producer fails to deliver the announced amount of electricity, TSO Fingrid Oyj handles the imbalance and costs are assigned to the producer. Fingrid thus controls the operational reserves in Finland. This is also the case for disturbance reserves, which are used to cover sudden failures in the power system. In the Nordic countries the total amount of disturbance reserve is set according to the largest unit in the market. This is divided between the countries in relation to the largest unit in each country (Holttinen 2004). Even large-scale wind power production would thus not affect the required level of disturbance reserves as long as wind farms are smaller than the largest production unit in the system, which in Finland are nuclear power plants Olkiluoto 1 and 2 in the municipality of Eurajoki, both having capacity of around 840 MW (Kara 2004).

The impact of large-scale wind power production on operational reserves is more ambitious. Impacts of wind power capacity growth on the power system are discussed in the Long-Term Climate and Energy Strategy (2008). It is estimated that increasing the installed wind power capacity to 2 000 MW would require around 240-350 MW of new operational reserves. These results are only preliminary, but indicate that growth in wind power capacity would have some impact on balancing power needs.

Perhaps the most comprehensive research on the topic of the Nordic markets is conducted by Holttinen (2004). The discussion about the reserves can be divided into two based on the operating time scale. Primary reserves are used to control variations within a time scale of seconds/minutes. Holttinen (2004) concludes that the even large-scale production of wind power is likely to have a very small effect on the system operation in the primary control time scale. Using a rough assumption that increase in wind power and its variations require the same addition to the primary reserves as increase in electricity demand and its variations, a 10 % share of wind power in total production would require an increase of 60 MW in primary reserves, which corresponds to about 0,3 % of wind power capacity installed (Holttinen 2004). However, in practice the primary reserves in the Nordic area amounted 600 MW in 2007 (Kristiansen 2007), which has been the situation for more than ten years. It is unlikely that growth in wind power capacity would change the situation, at least in the near future.

Secondary reserve refers to reserves that are used to control variation on a time scale of 10 minutes to 1 hour. To be exact, in the Nordic system there are no more secondary operational reserves defined due to the start of a regulatory power market. Sweden and Norway are now responsible for coordinating the frequency control and activation of reserves from the regulating power market according to net balance in the Nordic area (Holttinen 2004). However, the issue remains the same: reserves are used to cover imbalances, even though now through a market. In a study of Holttinen (2004) it was found in the simulations that when wind power is added to the power system, the existing Nordic reserve capacity will be used more. However, Holttinen (2004) suggests that with low wind power penetrations the increase in reserve requirements could be handled by existing reserves. Table 6-4 summarizes the increase in reserve requirements due to wind power with different penetration levels in Nordic market area. It should be noted that the increase of wind power capacity in Finland makes up only part of these figures. At the moment the wind power penetration level in the Nordic market is around 3 %, and therefore, if the Finnish capacity would rise to reach the ambitious goal of 2 000 MW by 2020 corresponding to 6 % penetration level in Finland, the Nordic penetration level would nonetheless remain just under 5 %, ceteris paribus. Thus it is evident from this chart that even quite dramatic growth in wind power capacity in Finland does not significantly impact the reserve requirements in the Nordic area.

Holttinen (2004) has also calculated the costs of increase in reserve requirements. The costs come from both the allocation and the actual use of reserves. Regulatory power is always more expensive than the bulk power because it is used in short intervals only and kept on stand-by at other times. In this way the increased use of reserves caused by wind power can be beneficial, because when reserves are used more, the price of regulatory power should decrease, assuming that there is enough capacity to cover it.

Table 6-4. The increase in reserve requirements due to wind power with different penetration levels. Source: Holttinen (2004)

	MW	% of peak load or capacity
Range of hourly variations Load	-985 – 1144	-7,2 – 8,4
Wind		-15,7 – 16,2
Stdev of hourly variations Load	268	2,0
Wind		2,6
Increase in variation, 2000-2002 data 5 % penetration	20	1,0
10 % penetration	80	2,0
20 % penetration	285	3,6
Increase in reserve requirements 5 % penetration	40	2,0
10 % penetration	160	3,9
20 % penetration	570	7,2

The exact cost of reserves depends on the production form, hydropower being the cheapest and gas turbines the most expensive. The cost of increased operating reserves in the Nordic power system according to Holttinen (2004) are 0,7 €/MWh for the allocation of capacity and 0,2 €/MWh for the use of reserves. These add up to 0,9 €/MWh at a 10 % penetration level of wind power. The estimates are based on a very conservative assumption that the investment costs of new reserves are allocated for the wind power production. If this assumption were replaced by a perhaps more realistic scenario according to which increased reserve requirements were covered with existing capacity, the figure for 10 % penetration would be only half of the figure mentioned above. It should, however, be kept in mind that the 10 % penetration would require a very dramatic growth in wind power capacity, not only in Finland but also in other Nordic countries.

The figures in Holttinen's (2004) study are somewhat smaller than the figures in the Long-Term Climate and Energy Strategy (2008). It can be concluded that within a time span of few decades it is not likely that increase in wind power capacity would have dramatic impacts on the reserve requirements, and the costs from balancing power are likely to be very small.

When considering impacts on power system, the correlation between wind power and electrical load (demand for electricity), as well as other variable production modes, is also important. If the correlation is positive, wind power is mostly available when also the demand for electricity is high. Respectively, positive correlation between wind power and other renewable energy sources signify whether they are available at the same time. This would be the case if for example wind would blew more at the times when also the rainfall is large.

The electrical load varies from day to day and hour to hour, being lower during the night than day and weekends than weekdays. According to Holttinen (2004), in Finland the correlation between load and wind power generation is 0,16, which signifies a slight positive correlation. Most of this can, however, be explained by the diurnal pattern of wind, which is mostly prevalent in summer. During wintertime there is very little correlation. This independence opens an opportunity to benefit from the complementarity of different variable energy sources. In Finland the most relevant case would be hydropower. Even though there is no correlation between dry and windy years, the distribution of production over the year can be beneficial. The peak of hydro inflow is in May-June, whereas wind power is more dominant in winter, October-February. Studies in other Nordic countries have shown that combining wind power with hydropower benefits the power system. (Holttinen 2004)

6.4.4 Competition

If the wind power makes up a larger share of the total production in the future, can this potentially also affect the competitive situation in the market. Due to its cost structure wind power has a competitive advantage compared to more conventional electricity generation forms; once wind power producer has entered the market, low marginal costs make sure that all the production will be sold and the production of the competitors replaced. Some of the competitors may have to exit the market after they are pushed further to the right in the supply curve thus being able to sell their production more infrequently. In the current Nordic market the production being sold most infrequently is generated by gas turbines and oil-fired condensing power plants, and therefore it would be reasonable to assume that these production forms would be in the greatest danger to be pushed out of the market by wind power.

However, in the long term it is profitability, not the marginal costs that determine which companies can continue on the market. While merit order reveals which production forms will suffer the most in their sales, it does not necessarily reflect the profitability of production. It is also noteworthy that many of the companies in the market have multiple production facilities utilizing different technologies. For example Fortum Corporation produces hydropower, condensing power, nuclear power, CPH as well as wind power. This means that rather than running some companies out of business, increasing wind power production can cause changes in their production mixes.

The impacts of wind power on the competition naturally depend on the overall development of the market. The Long-Term Climate and Energy Strategy (2008) forecasts that the total electricity consumption would grow from 90 TWh in 2007 to 103 TWh in 2020. The objective is to limit this increase so that the total use of electricity will not be more than 98 TWh in 2020. Thus even if the objective to stabilize electricity consumption growth were reached, it is forecasted to increase. This means that even though wind power would be able to take a larger share of total production in the future, other production would not necessarily have to diminish in real terms due to the fact that the market is growing.

In addition, the effects of wind power on the competition in the electricity market depend on the way it is subsidized by the government. All support schemes impact the functioning of the free market. Naturally, they also aim at supporting some technologies over others, but not all the effects on competition are necessarily welcome. Subsidies for wind power could, for example, prevent investments in other new capacity even if the capacity were necessary in extraordinary circumstances such as abnormally dry years. The challenge is thus to design a support scheme that encourages investing in renewable energy but does not distort the free competition too much. It would be intuitive that the less wind power producers are exposed to market risks the more the subsidies distort the competition. It is also notable that even if wind power capacity were to grow to 2 000 MW by 2020, its share of Finnish electricity consumption would be around 6 % depending on how the overall consumption develops. Because the production is sold in the common Nordic market, its share of the total demand would be significantly smaller. This means that even if wind power could bring about changes in the competitive situation of the electricity market, it is unlikely that these changes would be radical in the nearest decade even if wind power were heavily subsidized.

At the same time, government subsidies could also improve competition by encouraging new actors to enter the market. For example fixed feed-in tariffs guarantee a set price level and thus reduce risk to producers, which makes it easier for small suppliers to get financing. This reduces the need for a strong balance sheet to get into a market where initial investment costs are high and economies of scale play an important role. In Germany it has been noticed that fixed feed-in tariffs have encouraged small-scale, local wind power projects (GreenStream Network Oy 2007). It is also likely that if feed-in tariffs were adopted in Finland, this would attract new players to the Finnish market, where the circumstances are currently not very attractive to international actors (GreenStream Network Oy 2007).

6.5 Summary of the impacts

The impacts of large-scale wind power production on the Finnish electricity markets are summarized in the table 6-5. It can be concluded that the most central impacts from increased wind power production would be a reduction of CO_2 emissions and the costs from public support that need to be covered by taxes or additional fees for the electricity consumers. The public support needed to reach the goal of 2 000 MW of installed capacity are estimated to average 40 €/MWh for onshore and 37 €/MWh for offshore projects in the period 2008-2020 (GreenStream Network Oy 2007). The cumulative subsidies paid would in that case range between 1,3 and 1,8 billion euros by 2020 depending on the support scheme. These figures should however be taken only as rough estimates seeing that there are many uncertain factors that can substantially affect the actual costs, e.g. the prices of electricity and EUAs, and the discount factor used.

Increasing wind power production is found to cut the CO_2 emissions by 620-700 gCO2/kWh wind power produced (Holttinen 2004). This means that 6 TWh of wind power production corresponding to 2 000 MW of installed capacity would decrease CO_2 emissions by around 4,2-4,8 % in 2020. By multiplying the reduced emissions by the price of emission trading allowance EUA[10] it is found that the economic value of the annual emission reductions ranges between 55,5 and 63 billion euros. These figures are substantial compared to public support costs despite limitations discussed in section 6.1. If only one tenth of this income would materialize, the earning would still clearly exceed the public support costs. From this point of view supporting wind power to decrease emissions is beneficial also in economic terms. It should be noticed that the approach applied here only takes the explicit value from the opportunity cost of the allowances into account. However, the aim of the EU ETS is to contribute to the mitigation of the climate change that can have unpredictable consequences. Thus it is very difficult to assess whether there are also indirect benefits gained by the emission reductions[11].

[10] In the spring 2009 the price was ranging between 10 and 16 €/tCO2 (Vertis Zrt. 2006). Here 15 €/tCO2 has been used for calculations.

[11] Naturally the magnitude of the Finnish emission reductions is so small that alone they have a negligible impact on the mitigation of the climate change. However, as part of the process they can contribute to the outcome.

Table 6-5. Summary of the impacts of large-scale wind power production on the Finnish electricity markets.

Summary of the impacts of large-scale wind power production	
Emissions (CO2)	Wind power mostly replaces coal-fired condensing power. CO2 emissions will be reduced by 620-700 gCO2/kWh wind power produced.
Aural and visual impacts	Noise and landscape disamenities will increase along with increasing wind power capacity. Impact on housing prices is ambiguous.
Public support costs	Subsidies needed for increasing capacity to 2000 MW by 2020 will be average of 40 €/MWh for onshore and 37 €/MWh for offshore projects. By 2020 the cumulative costs from public support range from 1,3 to 1,8 billion euros depending on the support scheme.
Electricity price level	Wind power reduces spot prices by replacing production with higher marginal costs. With annual production of 6 TWh in 2020 the impact on the Nord Pool spot price would be 0,3 – 1,2 €/MWh.
Balancing power requirements	At small penetration levels likely no impact on reserve requirements, but the existing operational reserves will be used more.
Transmission capacity requirements	Installed capacity of 2 000 MW would require reinforcement of national main grid and building of a new connection between Finland and Sweden.
Competition	Due to negligible marginal costs, wind power in theory pushes other production forms out of the market according to the merit order. Public support can distort competition, but at low penetration level impacts are likely to be small.

Wind power is also found to have negative local impacts. Noise and visual presence of turbines in landscape would cause harm to residents and visitors in close proximity of wind farms. Due to most of the Finnish wind power potential being offshore, these aural and visual harms would be concentrated on the coastal area, which is also widely used for recreational purposes. The impact of these disamenities to property values is ambiguous, as even though no clear proof has been found to support the hypothesis that the presence of a wind farm near a residential building would affect property price, it is possible that this is caused by the limitations in the methodology used.

The impact of large-scale wind power on the Nord Pool spot market can be derived from the merit order. Due to virtually zero marginal costs wind power will replace other generation forms and thus shift the supply curve to the right. This will result in a decrease in the spot prices of electricity. If the Finnish wind power production in 2020 were around 6 TWh corresponding to installed capacity of 2 000 MW, the impact of the Finnish wind power capacity on the Nord Pool spot prices would be approximately 0,3 – 1,2 €/MWh depending on whether decrease in other production capacity is assumed.

The replacement of other generation forms naturally also affects the competition in the market. For production forms with higher marginal costs, wind power means a reduction in revenues, which may lead to postponed investments or even disinvestments. It should, however, be stressed that many of the largest companies in the market have utilize different technologies, and therefore rather than running some companies out of business, increasing wind power production might cause changes in their production mixes. Also the way wind power is subsidized by the government affects how large will the impacts on the competition be. However, at the Finnish penetration level of around 6 % this would be reached by installed capacity of 2 000 MW, the share of wind power on the common Nordic markets would remain very small. This means that it is unlikely that increase in the Finnish wind power capacity would cause any radical changes in the competitive situation in the Nordic electricity market during the coming decade, even when subsidized by the government.

Wind power potential is often distrusted on the grounds of its intermittency, which is presumed to cause sizeable new requirement to the power system. Based on the analysis in this chapter, this claim can be invalidated. It is likely that the impact of wind power on reserve power requirements will be very small, and the costs are estimated to be 0,45 €/MWh for a 10 % penetration in Nordic countries. The Nordic wind power penetration level is at the moment 3 %, and reaching the 10 % penetration requires very dramatic growth in wind power capacity, not only in Finland but also in other Nordic countries.

Large-scale wind power production would also have some impact on transmission grids that are originally designed for more concentrated and regular generation forms. Preliminary estimates show that installed capacity of 2 000 MW would require some reinforcements in the national main grid and building of a new connection between Finland and Sweden (Long-Term Climate and Energy Strategy 2008). It is, however, debatable to what extend these costs should be directed to wind power as also other producers contribute to the need for new transmission capacity.

In addition to the impacts discussed earlier, large-scale wind power production will presumably have some additional consequences that will be mentioned here only briefly. First, because wind power generation requires no imported fuels it is a very domestic energy source compared to more conventional CHP, nuclear and condensing power that all need imported inputs in order to operate. Thus increase in wind power production improves the self-sufficiency and the security of supply. Second, investments in wind power plants would also promote growth and bring jobs. Finland has already a significant amount of wind power related companies. In 2007 the wind energy sector turnover was roughly 500 million euros, most of this coming from exports (International Energy Agency 2008). These and new domestic companies would most likely also have a significant role in delivering the materials and building new power plants if wind power investments would start to increase in Finland. A more detailed analysis of these impacts is, however, left out of this study.

Finally, it should be stressed that the reference point of these analyses, the Finnish penetration level of approximately 6 % in 2020, signifies that wind power still has a rather small role in the electricity market, especially when looking at the whole Nordic market. It is clear that if the time scale of the study would have been longer, for example 20 or 50 years instead of slightly over a decade, also the impacts of wind power on the electricity markets could potentially be much more dramatic.

7 Conclusions

The objective of this research was to analyze the impacts of large-scale wind power production on the Finnish electricity markets. The main findings indicate that the most central consequences of the increased wind power production would be the reduction of the CO2 emissions and costs from the public support needed to achieve this increase. The cumulative public support costs were found to range from 1,3 to 1,8 billion euros by 2020 depending on the support scheme. CO_2 emissions were discovered to decrease by 620-700 gCO_2/kWh wind power produced. If the installed wind power capacity would increase to 2 000 MW by 2020, this would mean that CO_2 emissions were cut by 4,2-4,8 %. The economic value of the emission reductions was assessed by multiplying the CO2 abatement by the price of emissions trading allowance EUA. Despite limitations of this approach, the calculations suggest that depending on the price level of the allowances, the yearly economic value of the reductions could be tens of billions of euros, which clearly exceeds the costs needed to support growth in wind power capacity.

Increasing wind power capacity was also discovered to increase negative local impacts from wind farms such as noise and landscape disamenities. The impact on spot prices in Nord Pool would be lowering but small, approximately 0,3 – 1,2 €/MWh. Increased wind power capacity is unlikely to substantially increase reserve requirements in the power system by 2020, but it requires reinforcements of the national transmission grid and building of a new connection between the northern parts of Finland and Sweden. Also the impacts on competition were found to be rather small even though wind power can replace some old capacity of production forms with higher marginal costs.

Altogether, despite adverse local impacts, public support costs and new challenges for the power system, wind power was found to have potential to bring along substantial environmental and also financial benefits. It should be stressed that the subsidies paid to wind power are only interim expenses. They will not be paid forever, but only until technology develops to be cost-competitive with other electricity generation forms. The benefits from emission reductions in turn are continuous, so it is likely that especially in the long run the benefits of wind power will overrun the costs. Also, the negative impacts found need not to be taken for granted. For example, along with developing the cost-efficiency of turbines, attention should be paid in the aural properties in order to reduce the disamenities for the local residents.

In addition to the impacts of wind power on the electricity market, also the question of the most suitable support scheme for Finland to encourage investments in wind power was addressed in this study. It was concluded that there is no clear-cut answer to the best policy instrument. If the policymakers' priority is to rapidly increase installed wind power capacity this could be best achieved by adopting feed-in tariffs. There is, however, a risk that the costs from feed-in tariffs turn out to be very high. In the long run a more cost-efficient and less risky way to support wind power would be to develop current investment subsidy-based system further.

Simultaneously with the recognition of need for governmental support for wind power, discussion has arisen about new nuclear power projects. Low electricity price has historically been very important for the Finnish heavy industry, and nuclear power is seen to ensure availability of inexpensive electricity. However, from the point of view of the energy policy it would be inconsistent to both support renewable energies and give permissions for building new nuclear power plants. New nuclear capacity would decrease the electricity price and, as the support needed to make wind power cost-competitive equals the difference between production costs and market price, increase the need for public support for wind power. It would also decrease the incentives to invest money and energy to develop renewable energies further when the availability of inexpensive electricity would be guaranteed. This is problematic because of the EU obligation to increase the share of renewables have to be filled one way or another. Besides adverse effects on development of renewable energies, new nuclear power capacity would also encourage investments in energy-intensive production, which contradicts the structural change of the Finnish economy towards services. It is also questionable whether energy intensive manufacturing can be a future source of growth in Finland.

The main limitations of the results of this study relate to the general difficulties in forecasting the future. There is always uncertainty involved, and in the case of electricity markets for example development of wind power and other electricity generation technologies, prices of fossil fuels and the political decisions about how climate change will be addressed can greatly affect how wind power will impact the electricity markets and also the suitable support scheme for Finland. Hence the results presented here should be taken as estimations of the nature and magnitude of the impacts rather than exact figures.

Unavailability of relevant research on certain topics has also brought its limitations to this study. Especially the lack of Finnish research has been problematic since many of the impacts are assessed based on researches that have studied other countries than Finland. Because the electricity market structures are very different and function in different economic environments in different countries, it is not clear to what extend experiences of other countries can be applied to Finland. In addition, not all the possible impacts of wind power are covered in this study. As already mentioned, at least security of supply and development of wind power industry are topics that wind power capacity would probably have an impact on. Related industries might be affected as well.

Research on the impacts of the wind power on the electricity markets have been studied surprisingly little even though the topic is touched on in many other studies. Further research is needed particularly in Finland, where there already are political plans to increase wind power production but little research on many potential impacts such as visual and aural disamenities.

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