



NHH

NORGES HANDELSHØYSKOLE
Bergen, Fall 2011

*Master Thesis within the main profile of Energy, Natural Resources and
the Environment (ENE)*

Thesis Advisor: Professor Lars Mathiesen

The Debate About a Green Certificate Market in Norway
Arguments, Issues and Concerns

By:

Stina Maria Hope

NORGES HANDELSHØYSKOLE
Norwegian School of Economics

This thesis was written as a part of the Master of Science in Economics and Business Administration at NHH. Neither the institution, the advisor, nor the sensors are - through the approval of this thesis - responsible for neither the theories and methods used, nor results and conclusions drawn in this work.

Abstract

Norway and Sweden have agreed on a joint green certificate market applicable from January 1st 2012. This has caused debate. Scientists, politicians, environmentalists and others have expressed their concerns and issues related to the market regulation, where arguments have been inconsistent and conflicting. This study aims to make it clearer what these presented arguments, issues and concerns are, what they are based on and whether they can be supported by economic theory. The study has analyzed six topics, and conclusions have been drawn for every topic. Producer and end-user prices will decrease. Security of supply will increase, which will have a positive effect on the net energy balance. Volatility in the certificate prices will be reduced with the opportunity of certificate banking. The certificate measure will have marginal impact on CO₂-emissions. The measure will be cost-efficient and cause increased predictability of investment subsidies for RES seeking investors.

Table of content

Abstract.....	2
List of figures.....	5
List of tables.....	7
List of abbreviations.....	7
1.0 Outline and scope of the thesis.....	8
1.1 Introduction.....	8
1.2 Purpose and structure.....	8
1.3 Scope and limitations.....	9
2.0 Background.....	10
3.0 The energy market.....	12
3.1 Characteristics of the Norwegian energy market	12
3.2 Green house gas emissions and the RES-E Directive.....	15
3.3 Renewable energy sources in Norway.....	16
3.3.1 Wind power.....	17
3.3.2 Small-scale hydropower.....	18
3.3.3 Theoretical vs. real potential of renewable energy sources.....	18
3.3.3.1 Environmental factors.....	18
3.3.3.2 Economic factors.....	19
4.0 The green certificate market.....	21
4.1 The aim of green certificates.....	21
4.2 The functioning of a green certificate market.....	21
4.3 Price determination of green certificates.....	24

4.3.1	Minor production from renewable sources.....	30
4.3.2	Major production from renewable sources.....	31
4.4	The Swedish green certificate market.....	33
5.0	Discussion and analysis.....	38
5.1	Producer and end-user prices.....	38
5.2	Security of supply and the energy balance.....	45
5.3	Volatility in certificate prices.....	49
5.4	Impacts on CO ₂ – emissions.....	52
5.5	Cost-efficiency.....	57
5.6	Research and development	64
5.7	Predictability of investment subsidies.....	67
6.0	Conclusion.....	71
	References.....	73
	Appendix.....	80

List of figures

- Figure 1: Yearly electricity production (TWh) in Norway from 1960 to 2008
- Figure 2: Total end-consumption of energy (%) by energy commodity, 2010
- Figure 3: Determination of the system price at Nord Pool Spot
- Figure 4: Wind map of Norway: Wind speeds in 80 meters heights (m/s)
- Figure 5: How the certificate market will be harmonized with the power market
- Figure 6: Price determination in a green certificate market and the implications for the electricity market in the long run where demand is assumed to be elastic
- Figure 7: Box-and-whisker-diagram
- Figure 8: Box-and-whisker diagram illustrating both the system price volatility within a specific month and the month-to-month volatility in the system price for year 2010
- Figure 9: Box-and-whisker diagram illustrating both the system price volatility within a specific day and the time-to-time volatility in the system price for certain days of 2011
- Figure 10: Implications for the certificate price in a year with minor renewable energy production under the assumption of almost inflexible demand in the short run.
- Figure 11: Implications for the certificate price in a year with major renewable energy production under the assumption of almost inflexible demand in the short run.
- Figure 12: Average prices of green certificates in SEK from February 2003 to August 2009
- Figure 13: Price and volume effects of both traditional and green energy after the implementation of the green certificate market
- Figure 14: Changes in wholesale prices (NOK øre/KWh) with a quota of 8 TWh in 2016
- Figure 15: Changes in end-user prices with a quota of 8 TWh in 2016
- Figure 16: Clear three-way division of price levels with the hydro-area, Finland-Norway-Sweden at the lower end.
- Figure 17: Certificate price for consumers in SEK øre/KWh
- Figure 18: Export of energy and the effect of green certificates
- Figure 19: Illustration of effect of renewable investments on Nordic exports

- Figure 20: How banking might reduce the price volatility in the green certificate market
- Figure 21: Effects of green certificates in the traditional energy market
- Figure 22: Price per unit of emissions relative to level of emissions
- Figure 23: Efficiency gain when negative externalities of polluting goods are included in the supply
- Figure 24: Efficiency loss resulting from subsidising green energy production
- Figure 25: Cost of reaching the RES-E target for the two countries in autarky and in a joint market
- Figure 26: Norwegian research-, development- and demonstration budgets for energy purposes 1980-2009 in billion Euros
- Figure 27: Total amount of new wind power plants in Sweden and their installed capacity

List of tables

- Table 1: Annual Norwegian quotas from 2003-2035 and prognoses of new renewable energy production
- Table 2: The Swedish quotas from 2003-2035, prognoses of new renewable energy production and the real outcome of new renewable energy production.
- Table 3: Wind power capacity and growth rate Norway and Sweden, 2010

List of abbreviations

CCS	Carbon Capture and Storage
EEA	European Economic Area
GC	Green Certificates
GHG	Green House Gases
NGO	Non-Governmental Organisation
NOU	Official Norwegian Reports
NVE	Norwegian Water Resources and Energy Directorate
OED	Norwegian Ministry of Petroleum and Energy
R&D	Research and Development
RES	Renewable Energy Sources
RES-E	Electricity Production from Renewable Energy Sources
TGC	Tradable Green Certificates

1 Outline and scope of the thesis

1.1 Introduction

After years of negotiations, Norway and Sweden agreed on a joint green certificate market applicable from January 1st 2012. A market for green certificates is by many seen as the best suitable measure for increasing RES investments and to stimulate renewable energy production. The green certificate market debate has been flourishing in the media for as long as the thoughts about Norway implementing a green certificate market have existed. With interest and curiosity the author has followed this debate, as the certificate market measure has been honoured in one moment and strongly criticized in the other. Scientists and economists, socialists and environmentalists, politicians and traders have expressed their different views and opinions. The trend seems to be that politicians and NGOs are excited about the market regulation while economists and scientists have a more negative point of view. Nevertheless, statements and concerns are countless and conflicting, making it difficult and confusing for the common Norwegian electricity consumer to understand what the consequences of a green certificate market actually are. Some publications claim consumer prices of electricity would increase with a certificate market, while others state the market regulation would lead to the exact opposite. Various published articles emphasize how cost-inefficient subsidising renewable energy is and how off-guard the politicians are to engage in such a market regulation, while other research papers state the certificate market is a cost-efficient measure. Several NGOs have expressed their satisfaction with the green house gas emission reduction a certificate market would lead to, while economists on the other hand claim the green market would have zero or negative effect on emissions.

I hope this study will contribute to clarify the arguments, issues and concerns that have been presented in the certificate market debate. A special thank is given to my thesis advisor, Professor Lars Mathiesen for useful inputs, guidance and feedback along the way, and to all the people that have helped me reach the final result.

1.2 Purpose and structure

The purpose of this study is to identify and examine, what the author has found to be, the most important and relevant pro and con arguments, issues and concerns presented

in the green certificate market debate. This includes topics like producer¹ and end-user prices, security of supply and the energy balance, volatility in certificate prices, impacts on CO₂-emissions, cost-efficiency, research and development, and the certificate market's impact on the predictability of investment subsidies.

The paper will start with a presentation of the characteristics of the Norwegian energy market. Green house gases and the RES-E Directive will be emphasized, as well as the potential for some of the new renewable energy sources in Norway. A presentation of the green certificate market will follow. It will be explained what green certificates are, how the market works and how certificate prices are determined. Some experiences from the Swedish green certificate market will be given attention to at the end of the section. The latter part of the thesis will discuss the above-mentioned topics. Analysis will be conducted in order to see what the presented arguments of politicians, economists, environmentalists and others are based on and whether they can be supported by economic theory. The result of the analysis will be presented in a conclusion for every topic at the end of the study.

1.3 Scope and limitations

The focus of this study is to clear up the green certificate market debate. The aim is to make it comprehensible for the reader to see the impacts of the market regulation when it comes to producer and end-user prices, security of supply and the energy balance, volatility in certificate prices, impacts on CO₂-emissions, cost-efficiency, R&D and predictability of investment subsidies. The study does not engage in comparing the certificate market measure with other tools that could be suitable for promoting renewable energy and thus reaching the RES-E target.

¹ Producer prices refer to spot prices, i.e. the price traditional electricity producers receive for their production and the price green producers receive without the additional certificate subsidy.

2 Background

Global warming and energy crisis are some of the biggest challenges the world is currently experiencing. A global increase in temperature and the resulting consequences for future generations, carbon emissions, future energy supply and power prices are topics that get increased attention in the media. The global temperature is rising with increasing amount of CO₂ in the atmosphere. Simultaneously, the world is currently 90 percent driven by fossil fuels. The challenge is to make the world less dependent on fossil fuels, which both are finite resources and have negative environmental impact. Politicians and scientists have tried to reach a global agreement for reducing green house gases, however global treaties seem to be hard to achieve. The European Union has been seen as a pioneer in this area by capping emissions and implement ambitious targets for promoting electricity from new renewable energy sources. In 2009 the European Union introduced “Directive 2009/28/EC” also known as the RES-E Directive. The Directive requires that 20 percent of the total energy consumption within the EU must come from renewable sources by 2020. The Directive is part of the European Union’s 20-20-20-target, which includes

- 20% reduction in GHG compared to 1990-level by 2020
- 20% increased energy efficiency by 2020
- 20% of the total energy consumption from renewable sources by 2020

The RES-E Directive has been implemented in the EEA agreement, which Norway is a part of. That means that 67,5 percent of the Norwegian energy has to come from renewable sources within 2020, an increase of 9,5 percent from the current share of 58 percent. In 2008 the Norwegian political parties agreed on “Klimaforliket”, a Norwegian climate policy settlement. The settlement states that Norway aims to reduce its green house gas emissions by 30 percent by 2020 and be carbon neutral within 2030. Furthermore, the settlement claimed that Norway should engage in further negotiations with Sweden regarding a joint green certificate market. After years of negotiations the joint market became reality in June 2011, when Sweden and Norway agreed on having the same goal for the market outcome. The ambition is a combined target of electricity production from new renewable sources of 26,4 TWh by 2020, divided by 13,2 TWh for each country. The aim of the green certificate measure is to increase the security of energy supply through increasing renewable energy investments, promote environmental and climate targets and to facilitate more stable electricity prices. With

increased electricity production in Norway and Sweden, the countries would be less dependent on imported energy. Population growth both nationally and globally increases the demand for energy. Renewable energy sources could contribute to increase the electricity production, but these sources have proven to be relative much more expensive relative to hydropower and fossil fuels and thus cannot penetrate the market without subsidies. By introducing a green certificate market, new renewable energy sources would receive an additional income in terms of certificate revenue and thus more of these sources could be developed. A market for green certificates is therefore one example of a policy measure that could help Norway reach the RES-E target within 2020.

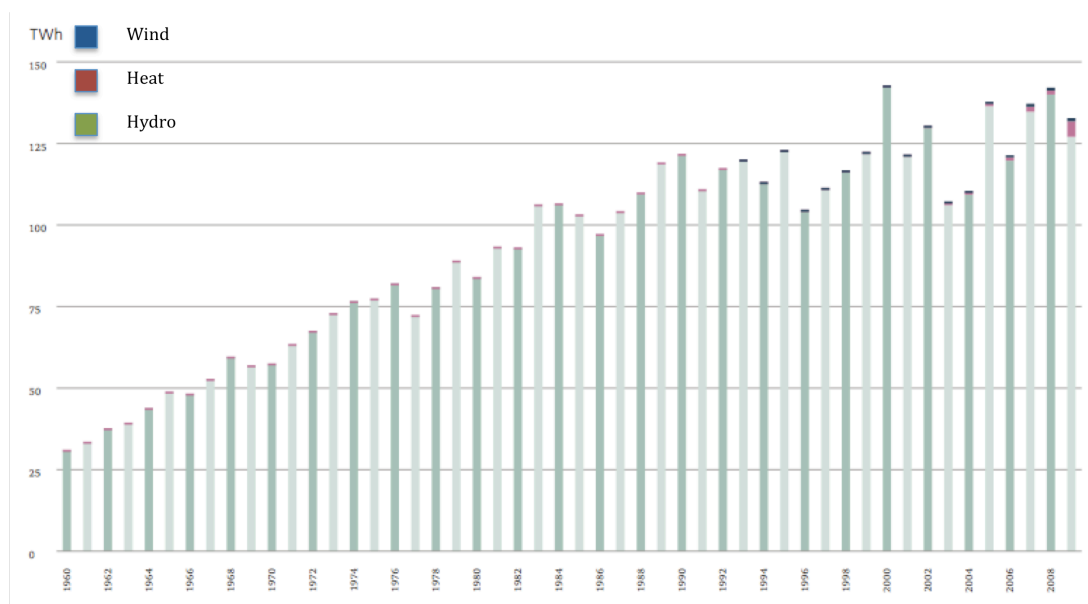
3 The Energy Market

A market for green certificates is dependent on the conditions and trends in the market for electricity. It is thus necessary to have some knowledge about the energy market in order to understand how a market for green certificates works and to perceive what the arguments, issues and concerns related to the regulation of a certificate market are based on.

3.1 *Characteristics of the Norwegian Energy Market*

The Norwegian energy market has some certain characteristics that make it different from energy markets in most other countries. First of all, Norway is rich on natural resources. Relatively cheap access to electricity from hydropower has made Norway rely on this source of energy for centuries. In a normal year² 99 percent of the Norwegian electricity originates from hydropower plants, while electricity production from wind and heat is marginal. The diagram in figure 1 illustrates hydropower's dominating position in the Norwegian electricity production from year 1960 to 2008, and how the production from heat and wind is lacking behind.

Figure 1: Yearly electricity production (TWh) in Norway from 1960 to 2008.



Source: Norwegian Water Resources and Energy Directorate (NVE), 2010.

Norway is the largest hydropower producer in the European Union and the sixth largest hydropower producer in the world (NVE, 2011). The development of hydropower

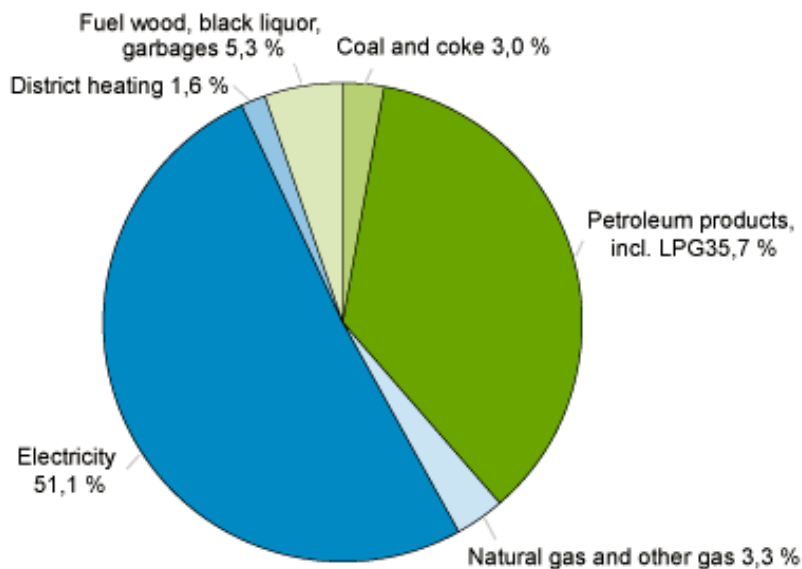
² A year with normal rainfall and temperatures is referred to as a normal year

plants in Norway has been growing rapidly during the last century and currently two thirds of the hydropower potential in Norway is already installed (NVE, 2011).

The abundant supply of hydropower has made Norway the largest consumer of electricity per capita in the world, as almost 50 percent of the total energy consumption in Norway (112 TWh of a total of 244 TWh in 2010) consists of electricity. In 2008 Norway consumed 27300 KWh of electricity per capita while the European average was 5700 KWh (Statistics Norway, 2011). This is partly due to the fact that electricity has been relatively cheaper in Norway compared to other European countries, thus electricity to a greater extent also is used for household heating. Most other countries rely on oil-based heating systems and are dependent on fossil fuels for their electricity production (Bye and Hoel, 2009). Prices on oil, coal and gas are relatively more expensive than hydropower, which naturally influences consumption.

Even though electricity from hydropower dominates the Norwegian energy consumption, petroleum products are other central resources, as can be seen in figure 2³.

Figure 2: Total end-consumption of energy (%) by energy commodity, 2010



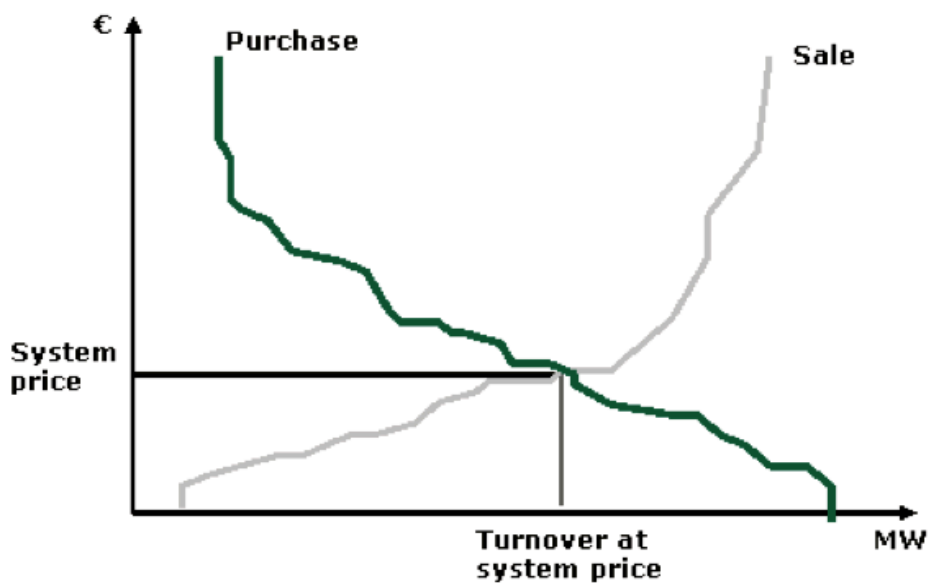
Source: Statistics Norway, 2011

³ A model (in Norwegian) of how the Norwegian energy system is functioning can be found in appendix A.

Petroleum products equal 35,7 percent of the total energy consumption in Norway in 2010. If we include coal, coke and gas, 43 percent of the energy consumption in 2010 came from carbon emitting sources.

The Norwegian electricity market has been liberalized since 1991. There are approximately 200 power-producing companies in Norway where 10 of these constitute almost 70 percent of all the production capacity (OED, 2008). At the Nordic multinational energy exchange, Nord Pool Spot, the balance between supply and demand determines the power prices in each pricing area within the Nordic area. 350 electricity companies from 18 countries operate on the exchange and in 2010 74 percent of all power in the Nordic region was traded at Nord Pool Spot. Figure 3 demonstrates how the intersection between purchases bids and sales bids determines the price of electricity for every hour of the day. This price is also referred to as the system price.

Figure 3: Determination of the system price at Nord Pool Spot



Source: www.nordpoolspot.com

The hourly system price for each pricing area is determined by the intersection of the aggregate supply and demand curves, which are representing all bids and offers of electricity for the entire Nordic region. Norway is divided into five different power price areas, where the prices depend on supply and demand of electricity in each area. Shortage of electricity production, grid constraints and bottlenecks cause higher system prices in some areas than others. When transmission capacity gets constrained, the price

is raised to create an incentive for the electricity suppliers in this area to increase their production and for consumers to decrease their demand in the areas affected (Nord Pool Spot). North- and Mid-Norway are areas where the electricity prices on average are higher compared to the rest of the country. Temperature, economic development and growth, prices on fossil fuels, rainfall, production capacities and prices on emission quotas are all factors influencing the system prices at Nord Pool Spot (Øydgard and Hansson 2010).

Norway has been switching between being a net exporter and a net importer of energy the last years. In 2010 the primary energy production decreased compared to the previous year (Statistics Norway, 2011). The production of oil decreased, so did the production of hydropower due to less water in the reservoirs. In 2010 the total energy production in Norway was 124,5 TWh, which was 6 percent lower than the year before. A decrease in energy production simultaneously as the demand for electricity increased caused a demand for imported energy. In 2010 Norway imported 7,5 TWh electricity and had a negative net energy balance, while in 2009 Norway had a positive net energy balance with an export quota of approximately 9 TWh electricity (Statistics Norway, 2011). Import and export of electricity is possible due to grid connections with other countries. Norway's electricity grid is currently directly connected to Sweden, Denmark, Finland, Russia and Holland (Statnett, 2008).

A reliable energy supply is an important target in the Norwegian energy policy. Norway wants to avoid being dependent on imported energy in the long term and aims to be self-supplied with energy from renewable sources in a normal year (NOU 1998:11).

3.2 Greenhouse gas emissions and the RES-E Directive

In 2010 Norwegian emissions of green house gases increased compared to previous years. The total amount of emissions was 53,7 million CO₂-equivalents, which is 4,8 percent more than in 2009. Increased metal production and an increase in transportation are to blame for the emission increase (Statistics Norway, 2011). Thus, it might seem that Norway's efforts of implementing a carbon tax on oil heating and transportation have not had the desired effect on the national CO₂-emissions. Norway aims to reduce its green house gas emissions by 30 percent within 2020 compared to 1990-level. Two thirds of the emission cuts will be done nationally, the other third through clean development mechanisms, which involve investing in emission-reducing projects such

as renewable energy, energy efficiency or fuel switching in developing countries where abatement can be done cheaper. Norway has furthermore agreed to reduce the emissions by 40 percent relative to 1990-level if this could lead to agreements on ambitious climate treaties where large carbon emitting countries like the United States and China are willing to commit to specific emission obligations (Klimakur, 2009).

Norway is a part of the EEA and is thus obliged to implement the European Union's Directive on Electricity Production from Renewable Energy Sources, also known as the RES-E Directive, which was introduced in the European Union in 2009. The aim of the directive is to increase the European Union's share of energy from renewable sources from 8,5 percent in 2005 to 20 percent in 2020 measured in relation to the member countries' total energy consumption. The RES-E Directive is one part of the European Union's 20-20-20 target⁴ as an attempt to combat climate change and global warming.

In order to reach the ambition of 20 percent renewable energy production each European Union member state has its own national renewable target, which in total will constitute the overall goal of 20 percent increase in energy from renewable sources within the European Union. Among the European Union member countries Sweden has the highest aim of 49,5 percent energy from renewable energy sources by 2020⁵. Norway's target is even more ambitious; 67,5 percent energy from renewable sources within 2020 (Blakstad, 2011).

In 2005 Norway had a share of energy from renewable sources of 58 percent. By 2020, an increase of 9,5 percent needs to be realized in order for Norway to reach the target of 67,5 percent energy from renewable sources. This demands a steeper growth in the development of renewable energy sources that add to the already existing sources in the Norwegian energy system.

3.3 Renewable energy sources

Renewable energy is energy from sources that do not run out and that do not have environmental impact on the world's climate in terms of carbon emissions. Hydro, wind, solar, wave, tide, osmosis, geothermal and biomass are some examples of renewable energy sources. In context of increasing RES investments, Norway has an

⁴ EU's 20-20-20 target: 20% reduction in green house gases, 20% increase in renewable energy production, 20% reduction in energy consumption through energy efficiency.

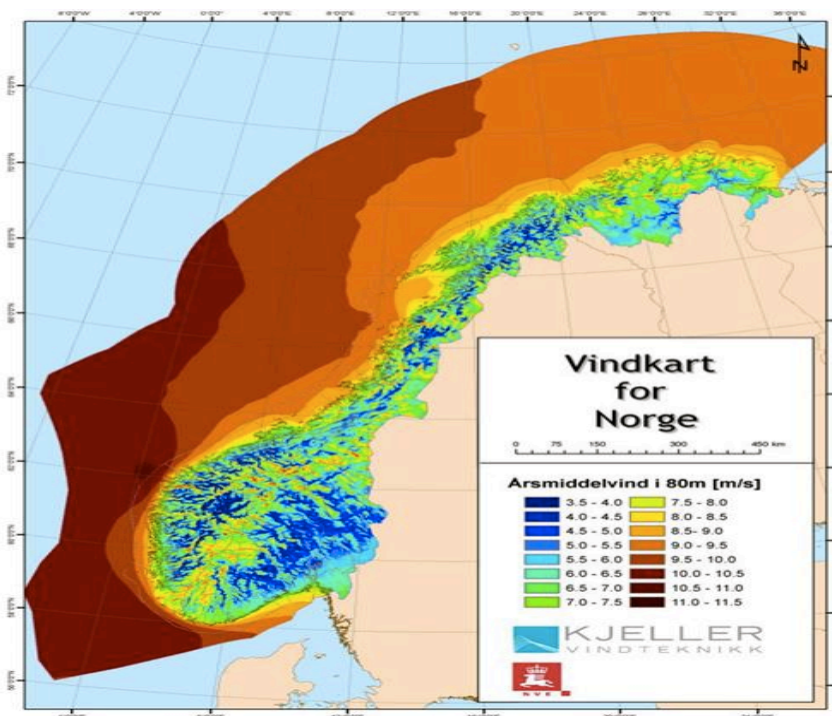
⁵ Refer to appendix B for a complete overview of each EU countries' RES-E targets.

advantageous position. With a long coastline and a topography characterized by high mountains, rivers and lakes the conditions are well suitable for energy production from wind and hydro. Even though hydropower is a well-established technology in Norway, new renewable sources need to be implemented in order for Norway to comply with the RES-E Directive, to ensure security of supply and to make an attempt to reduce emissions of green house gases from fossil fuels. In the next section of the thesis, the potential of wind energy and small-scale hydropower will be presented. These two technologies are assumed to be the dominating new renewable sources arising from the regulation of a green certificate market in Norway. The conditions for solar power are poor in Norway, technologies for oceanic energy sources are still too undeveloped and premature and use of biomass in Norway has been low due to protection of biodiversity and air pollution (Haugneland, 2007).

3.3.1 Wind power

With its long, windy coastline Norway has an advantageous position for generating energy from both onshore and offshore windmills. The total physical potential for wind energy in Norway is calculated to be several thousand terawatt hours per year. A wind map of Norway is presented in figure 4, specifying the conditions and wind speeds along the Norwegian coast in meters per second.

Figure 4: Wind map of Norway. Wind speeds in 80 meters heights (m/s)



Source: Norwegian Water Resources and Energy Directorate (NVE)

The map proves a great wind power potential for Norway with wind speeds up to 11 meters per second. However, large parts of this potential are not reachable due to environmental and economic factors (fornybar.no, 2011). In 2001 the Norwegian government announced a target of developing wind power plants that annual produce 3 TWh by 2010. Despite the ambitions ten years ago, Norway has still a modest electricity production originating from wind. In 2009 only 0,8 percent of the total energy production in Norway consisted of wind power (NVE, 2009). By the end of 2010 Norway has an installed wind capacity of 441 MW divided by 18 wind parks and 200 turbines (NVE, 2011). A comparison with other European countries states the fact that Norway is lacking behind. With 27214 MW installed capacity by the end of 2010 Germany is the European wind power champion. Also Sweden has a higher share than Norway; 2163 MW installed capacity by the end of the same year⁶.

3.3.2 Small-scale hydropower

Even though two thirds of Norway's hydropower potential already is developed, it is estimated that there is a remaining potential of 37,5 TWh per year. 25 TWh of this remaining potential comes from small-scale hydropower plants with yearly capacity below 10 MW (NVE, 2009). The potential is calculated from an upper investment limit of renewable production of NOK 3kr/KWh (NVE, 2009), which makes some of the predicted potential unprofitable without subsidies. The current power prices are too low to make these projects competitive on their own.

3.3.3 Theoretical vs. real potential

Even though the potential for wind and small-scale hydropower in Norway seems to be large, it is important to point out the difference between theoretical and real potential. The following sections present the environmental and the economic factors influencing the real potential of wind and small-scale hydropower in Norway.

3.3.3.1 Environmental factors

The NIMBY (Not In My Back Yard) phenomenon has in some cases proven to be an obstacle for wind farm development in specific areas. "Everyone" wants sustainable,

⁶ The European overview of total installed wind power capacity divided by country can be found in appendix C.

environmental friendly energy, but “nobody” wants to have the renewable power plants close to their neighbourhood where these plants might be noisy and disturb the natural landscape and the view. Additionally, due to the protected grounds and waterfalls some of the potential for further hydropower cannot be developed. 45,7 TWh of the total hydropower potential of 205,7 TWh (per year 2008) are located in protected areas and is hence not suitable for production (fornybar.no). Rarity and outdoor activities are factors influencing the decisions of the Norwegian Ministry of Environment whether certain areas should be protected or not, as development of hydropower plant often demands severe impacts in the nature and the landscape (NOU, 1998:11). In 2008 the remaining potential of hydropower that is not protected from being developed was 37,5 TWh per year.

3.3.3.2 Economic factors

At present stage energy production from renewable sources like wind cannot compete economical with the traditional and relatively cheap Norwegian hydropower. While there are no fuel costs associated with generating wind power, the investment costs of building a wind power project are large. The wind power industry is capital intensive. As much as 75 to 80 percent of the total cost is related to upfront capital costs, while the operation and maintenance cost attribute to the remaining 20 to 25 percent (vindkraft.no). Wind farms demand large material constructions and geographical areas, which makes the cost of this energy source significantly more expensive than hydro.

Producers of small-scale hydro are dependent on financial support for covering investment costs related to development of small-scale hydropower projects. A great share of these sources is located on private grounds or places where there are difficulties in connecting the production to the grid. In addition, small-scale hydropower projects often rely on sources that have either moderate water flow or are frozen during wintertime. Such production disruptions cause further competitive challenges for small-scale hydropower sources.

The experiences from Norway illustrate that if renewable energy sources like wind are required to compete under pure market conditions, the development of new renewable capacity will slow down or come to halt if policies are not introduced (Morthorst, 2000). Public subsidies to R&D, as well as demonstrations of energy technology, are provided through channels like the Research Council of Norway, Innovation Norway,

Enova SF and other governmental organs. Enova SF, an underlying organ of the Royal Norwegian Ministry of Petroleum and Energy relies on financial instruments and incentives to stimulate Norwegian wind power investments. Subsidies of renewable energy are a heavy burden on the public budget. In 2010 Enova SF provided approximately NOK 1 billion in subsidies to four onshore wind farm projects in Norway, and has since 2001 granted NOK 2,6 billion in subsidies of renewable energy projects (Enova, 2011). In Europe, more than 100 million Euros were taken from the public budget in 1998 only to subsidize wind turbines (Morthorst, 2000). The current system where governmental payments decide how much is being invested in renewable energy is vulnerable as it relies strongly on political will. In this context, the Norwegian government has suggested that a market for green certificates will be an appropriate tool to increase renewable energy production in Norway according to the RES-E Directive without the public budget bearing the costs.

Even though Norway is required by the European Union to obey the RES-E Directive, it is not a requirement to use the green certificate market as the measure for reaching the 2020-target. Every European country that is committed by the RES-E Directive has the right to choose the tool they think is the most appropriate for their own country. After years of negotiations, the Norwegian government concluded that a binding joint green certificate market with Sweden would be the best suitable measure for increasing energy production from renewable sources.

4 The Green Certificate Market

In the following part of the paper there will be given an introduction to the green certificate market. The price determination of the green certificate will be explained in addition to what influences the certificate price. Lastly, a short overview of and experiences from the Swedish green certificate market will be presented.

4.1 *The aim of a green certificate market*

The aim of a green certificate market is to ensure further RES investments. The target of the Swedish/Norwegian green certificate market is a development of new renewable energy technologies that in total produce 26,4 TWh of new renewable energy in Norway and Sweden combined by 2020 (OED, 2011). Increased development of new renewable energy sources will lead to improved security of energy supply, more stable energy prices and help reaching climate policy targets (Riis-Johansen, 2011).

A market for green certificate would release the government from its rather heavy burden of subsidising renewable technologies (Morthorst, 2000). After the introduction of a green certificate market, the additional costs of developing renewable energy will be transferred from governmental institutions to the consumers. Through their participation in the certificate market, electricity consumers will be subsidising the development of new renewable energy sources in both Norway and Sweden.

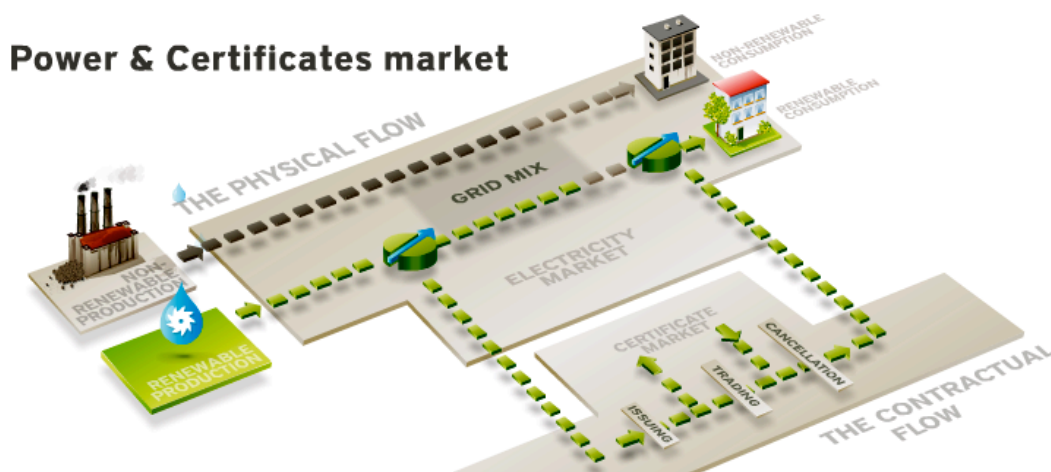
4.2 *The functioning of a green certificate market*

A market for green certificates is a subsidy scheme for promoting renewable energy production from wind energy, bio energy, wave energy, small-scale hydropower and solar energy. These sources are also referred to as *new* renewable energy sources⁷. As seen in the previous section, small-scale hydro and wind power are identified as the most promising of these technologies in Norway. There will be a purchaser commitment for the end-users to consume a certain share of new renewable energy of their total electricity consumption. However people living in the regions Finnmark and North-Troms will be exempted. By purchasing the compulsory green certificates, which is a guarantee that the energy originates from a new renewable source, consumers are ensured new renewable energy consumption. The electric utility companies are buying

⁷ In this paper the term "new renewable energy" would be used analogue to "green energy".

the required amount of certificates on behalf of their customers and add the cost to the consumer's electricity bills. The consumers are thus not directly involved in the certificate trading and the scheme requires no knowledge of certificate trading from the average end-user. Figure 5 is a theoretical visualization of how a green certificate market will be harmonized with the traditional power market. As we can see from the figure, the electricity market and the green certificate market will work as two individual markets.

Figure 5: How the certificate market will be harmonized with the power market



Source: www.ae.no

The energy authorities in Norway and Sweden will determine a specific renewable energy quota for every year up to 2035. This is a percentage share of the total energy consumption that should come from renewable sources. A complete table of the annual quotas and the corresponding forecasted new renewable production in Norway for the years 2012 - 2035 can be found in table 1. Certificates are being issued based on the level of the quota, and producers of new renewable energy receive certificates according to each megawatt hour of approved green electricity they produce. A penalty will be given to those consumers who do not comply with the mandatory amount of certificates, however energy intensive industries are exempted from participating. This is to ensure that these industries are not restrained by an excessively large additional certificate cost that makes them unable to maintain their international competitiveness in their respective markets.

Table 1: Norwegian annual quotas from 2003-2035 and prognoses of new renewable energy production

Year	Total electricity consumption	Amount of energy relevant for calculation	Green certificate quota	Total renewable production	New renewable production	Production being phased out
2012	118,0	74,3	0,030	2,22	1,47	
2013	118,3	74,5	0,049	3,68	2,93	
2014	118,7	74,7	0,069	5,15	4,40	
2015	119,0	74,9	0,088	6,62	5,87	
2016	119,4	75,2	0,108	8,08	7,33	
2017	119,8	75,4	0,127	9,55	8,80	
2018	120,1	75,6	0,146	11,02	10,27	
2019	120,5	75,8	0,165	12,48	11,73	0,03
2020	120,8	76,1	0,183	13,92	13,20	0,03
2021	121,2	76,3	0,182	13,89	13,20	0,03
2022	121,6	76,5	0,181	13,86	13,20	0,04
2023	121,9	76,7	0,180	13,82	13,20	0,05
2024	122,3	77,0	0,179	13,77	13,20	0,15
2025	122,7	77,2	0,176	13,62	13,20	0,21
2026	123,0	77,4	0,173	13,41	13,20	0,21
2027	123,4	77,7	0,170	13,20	13,20	1,47
2028	123,8	77,9	0,151	11,73	11,73	1,47
2029	124,1	78,1	0,131	10,27	10,27	1,47
2030	124,5	78,4	0,112	8,80	8,80	1,47
2031	124,9	78,6	0,093	7,33	7,33	1,47
2032	125,3	78,8	0,074	5,87	5,87	1,47
2033	125,6	79,1	0,056	4,40	4,40	1,47
2034	126,0	79,3	0,037	2,93	2,93	1,47
2035	126,4	79,6	0,018	1,47	1,47	1,47

Source: Norwegian Ministry of Petroleum and Energy (OED)

Green electricity producers receive an income from the certificates they sell in addition to the system price they get from their electricity production. That means that with a green certificate market, producers of renewable energy will gain a higher income than prior to the market regulation. This higher return can be used to cover the relatively higher costs. New renewable sources that earlier could not be developed and thus not enter the market due to high development costs and in-competiveness, are now able to sell their green energy in the market, as the additional certificate price covers more of their development costs. The average electricity price in Norway in 2009 was NOK 36,3 øre/KWh, hence the development cost of renewable projects could not exceed 36,3 øre/KWh in order to be put into operation. In Sweden in the same period the price of a green certificate was NOK 24,2 øre/KWh. Given these prices, calculations show that production from renewable energy sources with development costs of up to NOK 60,5

øre/KWh could penetrate the electricity market after the implementation of the green certificate market (fornybar.no).

The green certificate market will be technologically neutral. Neutrality of technology means that the most profitable energy projects will be developed first, regardless of source. All varieties of new renewable energy sources can be included in the scheme except from the well-established, large-scaled hydropower plants. Since this is an already competitive and profitable technology, it is not dependent on the extra subsidy income from the certificates. However, newly developed hydropower plants with a maximum production capacity of 10 MW that need the extra income in order to be able to enter the energy market, will be included in the scheme. The green certificates are to be sold at the Nordic power exchange, Nord Pool Spot. The decisions from the energy authorities regarding the renewable quotas for each year determine how many certificates that will be demanded.

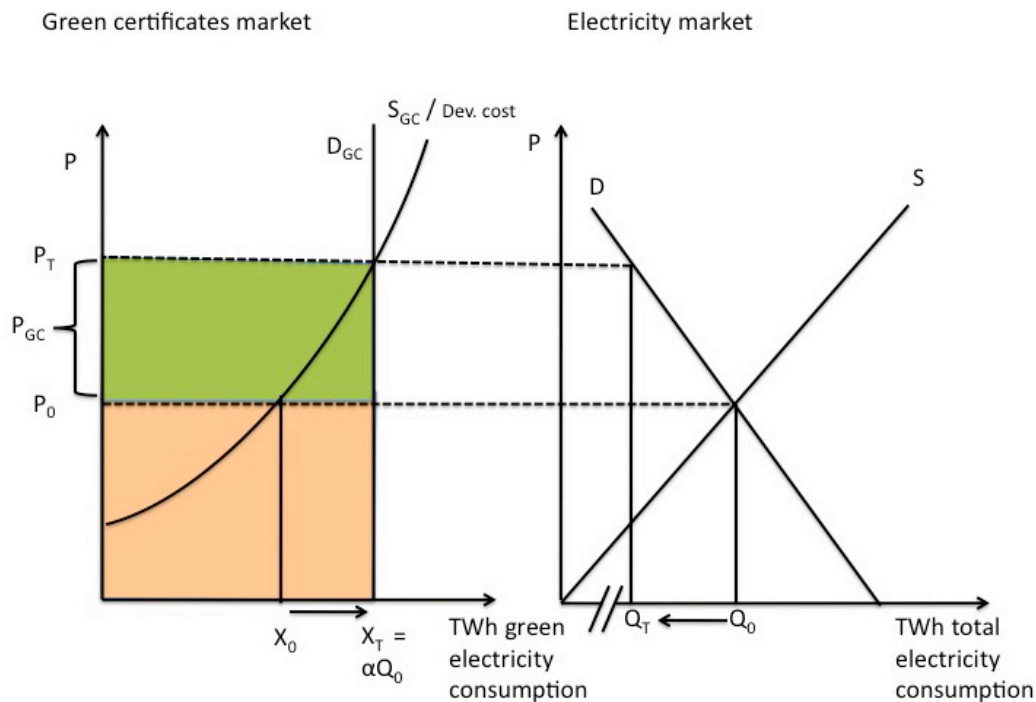
The development of a separate green certificate market is one of several models generating additional payments to renewable technologies. This model will facilitate the integration of renewable into the liberalized market and at the same time make it possible for these technologies to be partly economic compensated for the environmental benefits they generate compared to conventional power production. The Netherlands has had a voluntary green certificate market since the beginning of 1998 (The Green Label), England and Wales since 2002 (UK Renewables Obligation Certificate Market), Italy, Austria and Belgium have also implemented certificate markets, while Sweden has had a binding green certificate market since 2003.

4.3 Price determination of green certificates

The price of the green certificates is determined by the intersection of supply of new renewable energy sources that have the right to be assigned certificates, and the required demand of certificates in the separate green certificate market. The supply curve represents the available new renewable energy sources given by increasing development costs of the source. A ranking of electrical sources in order of their short-run marginal costs of production is in theory referred to as a merit order. The supply curve in the green certificate market is thus a merit order curve. The required demand for the green certificates is dependent on the level of the renewable energy quota (in TWh) issued by the energy authorities for each specific year. The quota is given by the

symbol alpha (α) and imposes the consumers how much of their electricity consumption that needs to come from new renewable sources. The level of the quota will be at its highest in 2020, when 18,3 percent of the consumers' total electricity consumption has to come from green sources. The demand curve for green certificates represents the required annual quota and is thus inelastic⁸ on an annual basis, illustrated by a vertical demand curve in the certificate market in figure 6.

Figure 6: Price determination in a green certificate market and the implications for the electricity market in the long run where demand is assumed to be elastic



Source: Own figure

The system price for electrical power, P_0 is determined as normal in Nord Pool Spot's hourly spot market. The intersection between bids and sales determines the price of electricity for each hour of each day, as can be seen in the right part of figure 6. Purchase bids are analogue to demand while sales bids equal supply. Figure 6 is a long-term market diagram, thus the demand for electricity is assumed to be elastic. The two parallel lines on the X-scale in the electricity market illustrate that this market is relatively much larger than the market for green certificates, i.e. the quantity generated is of a much larger scale. A system price equal to P_0 will generate an output of Q_0 TWh of total electricity consumption and a level of X_0 TWh of new renewable energy in the

⁸ Due to the relation to electricity consumption a small price elasticity might exist (Morthorst, 2000). Figure 6 is drawn with totally inelastic demand.

market. This level of green energy, X_0 is currently too low according to the RES-E Directive, and has to increase by 9,5 percent within 2020.

By regulating the green certificate market, the government requires that a certain annual level of electricity must come from new renewable sources. This quota is equal to X_T TWh, where $X_T = \alpha X_0$ indicates that the amount of green electricity in the market should be equal to a percentage (α) of the total domestic electricity consumption. Electric utilities on behalf of their consumers are obliged to ensure that renewable energy consumption reaches this specific level. By requiring a share of new renewable energy equal to X_T and simultaneously impose consumers to buy certificates, will cause the consumer price of electricity to increase from P_0 to P_T . The difference between the total price, P_T and the initial electricity price, P_0 gives us the price of one green certificate, P_{GC} . Since producers of energy from new renewable sources now receive a higher price P_T , which is the sum of $P_0 + P_{GC}$, new renewable energy sources that earlier used to be too expensive and thus unprofitable to penetrate the market now can be developed. Due to technological neutrality and increasing development costs, the most profitable sources will be developed first and more expensive sources will follow as the quota increases. Traditional electricity producers and energy intensive industries still receive and pay the initial system price P_0 , and traditional electricity producers will thus not see an increased producer surplus due to the new market implementation, as would be the case for the green producers.

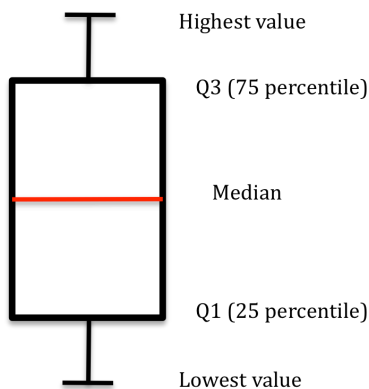
The certificates can be seen as subsidies to producers of new renewable energy, while for the consumers who are required to buy certificates the scheme is analogue to an electricity usage fee. This is explained in figure 6 as the consumer price in the electricity market increases, given by $P_0 + (\alpha * Q_0) * P_{GC} = P_T$. Demand for electricity is in the long run assumed to be elastic, i.e. if possible, consumers switch to other sources of energy when electricity prices increases significantly. Thus, the total electricity consumption decreases to Q_T TWh in the long run. Therefore, with no other factors taken into account, introduction of the green certificate market will lead to higher prices for the consumers who in the long run may respond by demanding less electricity.

In addition to the level of the annual green certificate quota, the system price of electricity determined at the energy exchange influences the price of the certificates. Since 99 percent of the electricity production in a normal year comes from hydropower and it is expected that wind power will increase its share of the total energy production,

weather conditions like rainfalls and wind speeds could lead to significant volatility in the system price and thus also the price of the certificates. Volatilities in the certificate price cause consequences for the green producers, as their revenue would be unpredictable when the certificate price varies, and for the consumers' electricity expenditures.

A box-and-whisker diagram can be used to illustrate volatilities of values over time. How to interpret such a diagram is shown in figure 7. The highest and lowest values are respectively the highest and the lowest system prices within the period. Q3 is the third quartile (also referred to as 75 percentile), i.e. the value of which 75 percent of the prices are below. Q1 is the first quartile (25 percentile), i.e. the value of which 25 percent of the prices are below. The median value is where 50 percent of the values are above and 50 percent of the values are below.

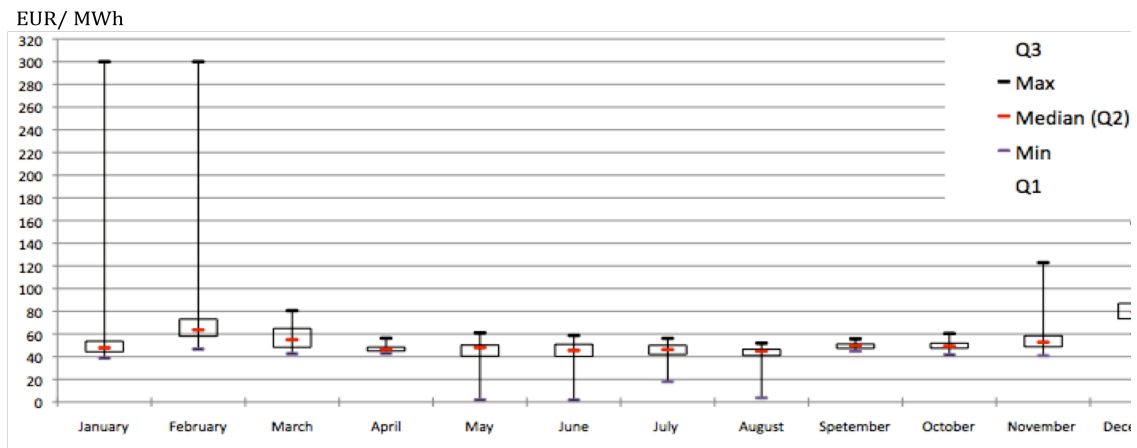
Figure 7: Box-and-whisker-diagram



Source: Own figure

The box-and-whisker diagram in figure 8 is based on system price data from Nord Pool Spot. It shows the system price on an hourly basis grouped for the months of the year in 2010. The hourly system price throughout the year is collected to get the most accurate picture of the price volatility that exists in the Nordic power market.

Figure 8: Box-and-whisker diagram illustrating the system price volatility within a specific month and the month-to-month volatility in the system price for year 2010

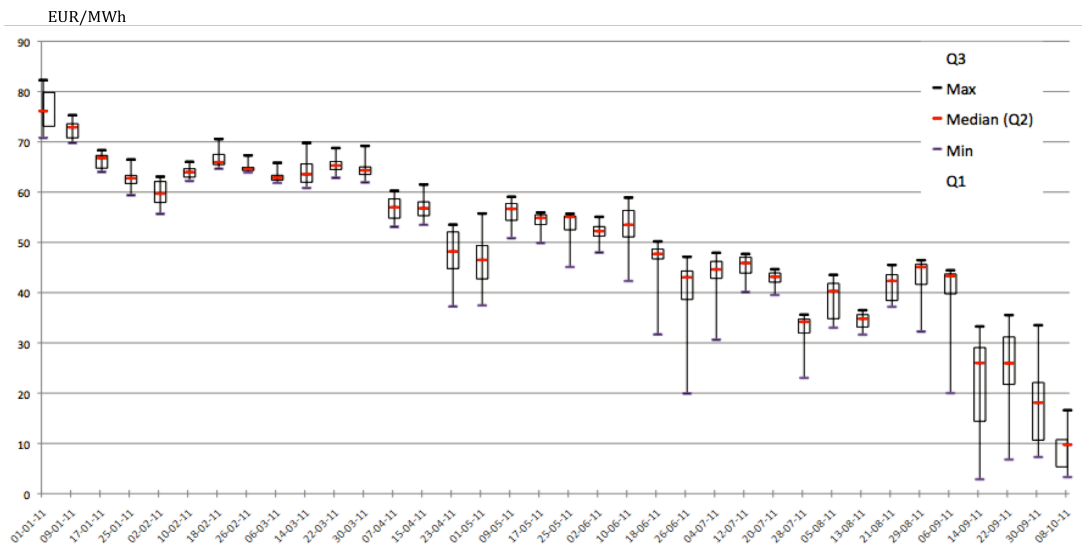


Data source: www.nordpoolspot.com

The highest system prices in 2010 were observed in January and February, where the price reached 300,03 EUR/MWh. This can be explained through increased demand for electricity due to cold weather and lower supply due to frozen reservoirs and more snow than rain. The lowest observed values were in May and June with a system price as low as 1,8 EUR/MWh. Snow is melting during the spring causing increased supply and thus lower prices. From the graph we also see that the volatility within a month is greater during wintertime than in the summer. January was the most volatile month, while in April and September the prices were relatively stable. When hydropower producers are able to regulate their reservoir levels, the price volatility decreases. Due to shifting reservoir levels, inflow and temperatures, regulation becomes more difficult during wintertime than during spring and autumn.

Furthermore, figure 9 illustrates the volatility on a day-to-day basis for some randomly selected days of the year in 2011. From the diagram we see that even during a day the volatility can be high, which for instance was the case for the dates 26.06.11 and 14.09.11. Daily volatility can be explained due to peak and off-peak hours. Mornings during the week is normally peak hours, since numerous people get up at the same time, take a shower and use electric devices for breakfast cooking etc. Nights are referred to as off-peak hours when people are sleeping and thus use a minimum of electricity. In figure 9 below we see that the volatility is larger in the summer time and during the fall than in January – March. During the winter, the demand will be continuously high due throughout the day household heating.

Figure 9: Box-and-whisker diagram illustrating both the system price volatility within a specific day and the time-to-time volatility in the system price for certain days of 2011



Data source: www.nordpoolspot.com

The certificate price increases or decreases due to changes in the system price, which has been proven to be volatile on both a monthly and a daily basis. Production from renewable energy sources is dependent on rain- and wind conditions, while at the same time dependent on how much is being invested in the development of these technologies. Financial crises play a crucial role when it comes to R&D of renewable technologies, i.e. the investments in clean and perhaps new technology decrease significantly in periods with financial instability and recessions. After the global financial crisis, clean tech investments dropped from \$4.088 billion in 2008 to \$154 billion in 2009 (PwC, 2009). Even though this is not a topic covered by this thesis, it is worth mentioning that even with a market for green certificate, financial turmoil causes significantly declines in development, while booms in the economy on the other hand lead to increased development of new renewable energy sources.

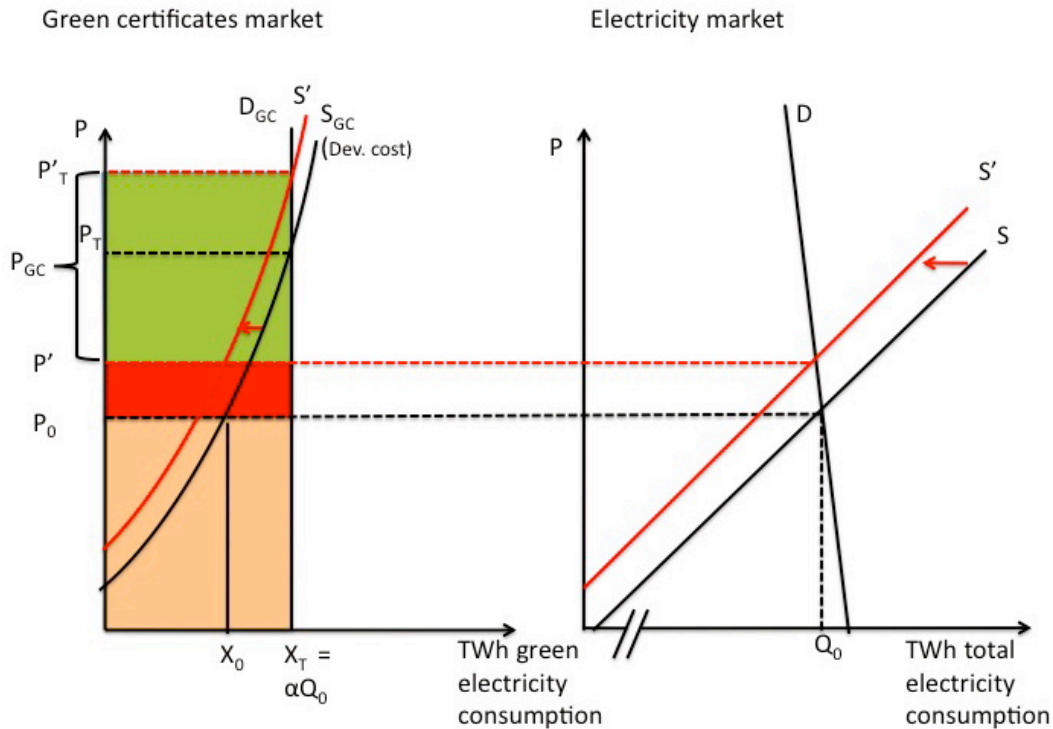
Rainfall and wind speeds will be other factors influencing the development of new renewable energy sources in Norway on an annual basis. A year with minor production from renewable sources due to weather conditions causes an increasing certificate price and thus higher revenue for the green producers, ensuring profitability of new projects. A year with major renewable energy production will on the other hand lead to the opposite. The following section gives an analysis of these two scenarios and how the certificate price is being affected.

4.3.1 Minor production from renewable sources

Since approximately 99 percent of the electricity production in Norway comes from hydropower, a dry year will cause a decrease in the electricity production. This is indicated by an inward shift in the supply curve in the electricity market, which makes the system price increase. The demand for electricity is assumed to be inelastic within a year, illustrated by a vertical demand curve. Even though the domestic electricity production decreases, import of electricity makes it possible to maintain the same amount of electricity consumption even in a year with minor production from renewable sources. The supply of new renewable energy sources will also decrease, as most of the new renewable energy production in the green certificate market is expected to come from small-scale hydro and wind power, which are significantly dependent on weather conditions. Since the green electricity sources only constitute approximately 10 percent of the total electricity production, the inward shift in supply from renewable energy sources in both markets will have a significantly larger impact in the smaller certificate market than in the larger electricity market. The new renewable production might therefore be too low to cover the required renewable energy consumption given by the annual quota, which is being held at a fixed percentage level throughout the year. Since the demand for the certificates will be larger than the supply of certificates, the price of the certificates will increase due to scarcity of supply in the amount of certificates in the market. The effect of a dry year with modest wind speeds is thus that the certificate price will increase, as can be seen in figure 10⁹. Since the certificate price increases with decreasing production from new renewable sources, the government has decided on a maximum price for the certificates. A maximum certificate price would ensure that consumers are not suffering due to the consequences of an unlimited certificate price.

⁹ The supply curve in the green certificate market represents a merit order curve.

Figure 10: Implications for the certificate price in a year with minor renewable energy production under the assumption of almost inflexible demand in the short run.



Source: Own figure

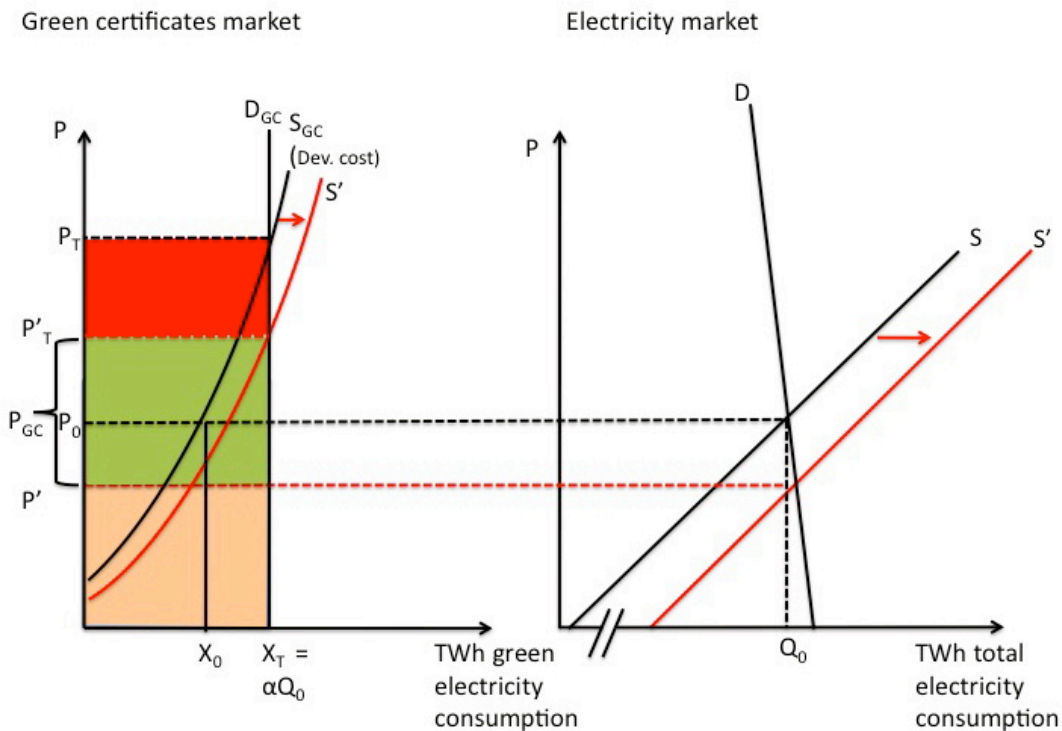
Some consumers might not be able to buy the required amount of certificates they are obliged due to the scarcity of supply, and thus have to pay the penalty price for not covering their renewable share. In Sweden the penalty fee is 150 percent of the average green certificate price from the previous 12 months (Rydén et al., 2006). A higher total electricity price for the consumers due to higher certificate- and system price leads to a decrease in the total demand for energy in the long run. When the total energy consumption decreases, the share of renewable energy consumption also decreases. This is affecting the green producers, as the demand for their production will decrease in the long run.

4.3.2 Major production from renewable sources

A reverse scenario will lead to the opposite. A windy year with heavy rainfalls will cause the production of renewable energy sources to increase from S to S' , illustrated by an outward shift in the supply curve in both the electricity market and the green certificate market. Since increased production from new renewable sources causes an outward shift in the supply, additional new renewable energy sources can be developed

and thus more certificates will be issued. Since there are more certificates on the market, the price of the certificates will decrease, leaving the green producers with lower additional income per certificate. This can be seen from figure 11¹⁰ as the certificate price decreases to a level equal to the difference $P'_T - P'$, which is a lower income per certificate for the green producers than in the above scenario.

Figure 11: Implications for the certificate price in a year with major renewable energy production under the assumption of almost inflexible demand in the short run.



Source: Own figure

When the price of the certificates decreases, green producers could have problems covering their costs. If the decreased return per certificate cannot be counterbalanced by increased green production, which would mean additional certificates and thus additional certificate income, green producers would lose profit. In that case, “a minimum price” of the certificates decided by the energy authorities could be life saving for many of these premature technologies and ensure new renewable sources still are being developed despite decreasing certificate price.

As the above analysis have illustrated, a wet and windy year causes the amount of certificates to increase and thus the certificate price to decrease, while a dry and non-

¹⁰ The supply curve in the green certificate market represents a merit order curve.

windy year on the other hand leads to an increase in the certificate prices. However, major production from renewable sources due to wet and windy years causes lower spot prices and thus consumers might demand more electricity in the long run. As a certain share of the consumers' electricity consumption has to come from new renewable sources, the demand for green energy might thus also increase.

The above scenarios have shown that wind and water conditions are among many of the factors influencing the system price, which in turn influence the price of the green certificates. In order to avoid serious fluctuations in the price of the green certificates it is important that the government finds the best suitable quota for their desired share of green energy in the market. Wind and water conditions are difficult to forecast ahead of time when the required quota for each year is to be decided. It is impossible for consumers to use a specific share of renewable energy if the weather conditions do not allow sufficient production. Nevertheless, in order to avoid severe volatility in the certificate prices that will have consequences for both the renewable energy producers and for the consumers' variable energy expenditures, it is important to set the renewable energy quota as accurate as possible for every year. Experiences from the Swedish green certificate market have shown that a quota that is not correlated to the volatility in the system price has its consequences, as the revenue for the green producers are dependent on their income from the certificate price. However, both maximum prices (the penalty price) and minimum prices could get rid of some of the most severe consequences for both producers and consumers. Another measure to ensure increased price stability is to issue certificates without a due date. This would give consumers the ability to buy and store certificates when the price is low and use them for years where the demand for and the price of the certificates are higher. Some of the variability in the certificate price could thus be evened out, which will be more detailed discussed in a later part of the paper.

4.4 The Swedish green certificate market

Sweden has had a green certificate market since 2003. In the context of Norway joining this market, it is interesting to see how well the market has been functioning in terms of increases in new renewable energy production.

As a member of the European Union, Sweden has a target of 49,5 percent energy from renewable sources within 2020 and aims for a share of at least 50 percent after that. The

Swedish government states that the green certificate market is the most important tool for increasing electricity production from renewable energy sources, with an ambition of 25 TWh increase in electricity from new renewable sources by 2020 compared to 2002-level (Prop.2008/09:163).

For each megawatt hour of new renewable energy produced, Swedish green producers receive one certificate. Energy sources with the right of being assigned green certificates in Sweden are wind, wave, solar, geothermal, peat, biomass and hydropower (Swedish National Grid, 2011). Small-scale hydropower plant with a maximum installed capacity of 1,5 MW by the end of 2003, in addition to newly installed or restored hydropower plants or plants that are not qualified for long-term profitable production, are included in the scheme (Swedish Energy Agency, 2009). With respect to existing hydropower, Swedish and Norwegian authorities differ in their view on what should constitute small-scale hydropower. Norway is more inclined to accept a more generous capacity limit (10 MW) than Sweden (1,5 MW). Producers of energy from the above mentioned renewable sources in Sweden are assigned certificates for a period of 15 years. Energy intensive industry is exempted from participating in the required green certificates market, just like would be the case for the similar industry in Norway.

Swedish energy authorities have calculated the green certificate quotas up to year 2035. The quota for every year (in percent of total electricity production) can be found in table 2, as well as the forecasts for how much new renewable energy they are expecting to be generated given each year's quota. The last column in the table shows the real outcome of new renewable electricity production. By the end of 2009 an accumulated increased production of 9,06 TWh electricity from new renewable sources had been generated in Sweden from 2003. From the same calculations, Sweden will reach the target of 25 TWh accumulated electricity from new renewable sources in 2020 by a quota that year of 19,5 percent. The years following from 2020, the quotas in the Swedish green certificate market will decrease until year 2035 when the market will cease to exist.

Table 2: The Swedish quotas from 2003-2035, prognoses of new renewable energy production and the real outcome of new renewable energy production.

Year	Quota (%)	Forecast of new renewable electricity production (accumulated) (TWh)	Real outcome of new renewable electricity production (accumulated increase) (TWh)
2003	0,074	-	1,96
2004	0,081	-	4,55
2005	0,104	-	4,80
2006	0,126	-	5,66
2007	0,151	-	6,76
2008	0,163	-	8,54
2009	0,170	9,31	9,06
2010	0,179	10,81	
2011	0,179	11,84	
2012	0,179	12,94	
2013	0,135	14,80	
2014	0,142	16,26	
2015	0,143	17,71	
2016	0,144	19,17	
2017	0,152	20,63	
2018	0,168	22,09	
2019	0,181	23,54	
2020	0,195	25,00	
2021	0,19	25,00	
2022	0,18	25,00	
2023	0,17	25,00	
2024	0,161	25,00	
2025	0,149	25,00	
2026	0,137	25,00	
2027	0,124	25,00	
2028	0,107	25,00	
2029	0,092	25,00	
2030	0,076	25,00	
2031	0,061	25,00	
2032	0,045	25,00	
2033	0,028	25,00	
2034	0,012	25,00	
2035	0,008	25,00	

Source: Swedish Energy Agency, 2009.

The forecasted amount of accumulated new renewable electricity production in Sweden by the end of 2011 was 11,84 TWh. In order for Sweden to reach their target of 25 TWh increase in electricity from new renewable sources within 2020 compared to 2002-level, the remaining amount of increased renewable energy production in 2012 is

13,16 TWh. From January 1st 2012 Norway will be entering the Swedish market and will thus have the same targets as Sweden. That means that from 2012 and by 2020 there will be developed of at least 26,32 TWh new renewable energy in these two countries combined as a result of the joint green certificate market.

During the three first years of the Swedish green certificate market it was issued more certificates than demanded. This led to an over-supply of certificates in the market and caused the prices of the certificates to decrease. The accumulated surplus of certificates lasted for three years, as the certificates were issued without a due date and could be saved for later years when the prices were higher. In 2006 the market experienced a change, as the amount of annulled certificates exceeded the amount of issued certificates (Swedish Energy Agency, 2010). This caused an increase in the certificate price as can be seen from figure 12.

Figure 12: Average prices of green certificates in SEK from February 2003 to August 2009



Source: Swedish Energy Agency, 2010

Figure 12 shows the development of the certificate price in Sweden from February 2003 to August 2009. From 2003 to 2006 the certificate price decreased, followed by an increase from 2006. A sudden change from decreasing certificate price to increasing certificate price could mean that several of the projects with lower development cost had been installed and that currently more expensive projects were being developed. Increased development costs as more expensive projects were put into operation

affected the certificate price, as shown in figure 6. Prior to the introduction of the green certificate market, Sweden had already developed several biomass power plants. With its large forests and land areas, Sweden has good conditions and knowledge for producing biomass at relatively low cost. When the green certificate market first was introduced, biomass covered most of the demand from new renewable energy. As the demand for additional new renewable energy increased as the quotas were increased, other more expensive sources had to be developed. Wind power plants were some examples of this. From 2006 the amount of wind power plants in Sweden increased, despite only generating a total of 2,5 TWh by the end of 2009 (Swedish Energy Agency, 2010).

Even though Sweden had some start-up problems related to the issuing of certificates when the market first was introduced, the market has helped stimulating increased production of new renewable energy in the country. By the end of 2009 the real level of new renewable energy had reached 9,08 TWh (see table 2). The Swedish consumers' total cost for the certificate market was SEK 3,8 million in 2007, where SEK 0,8 million accounted for VAT (Prop.2008/09:163). It is reasonable to believe that Norway would take Sweden's preface problems into account when the market expands to include Norway from January 1st 2012, and thus avoid some of the start-up problems as were seen in the Swedish market.

5 Discussion and analysis

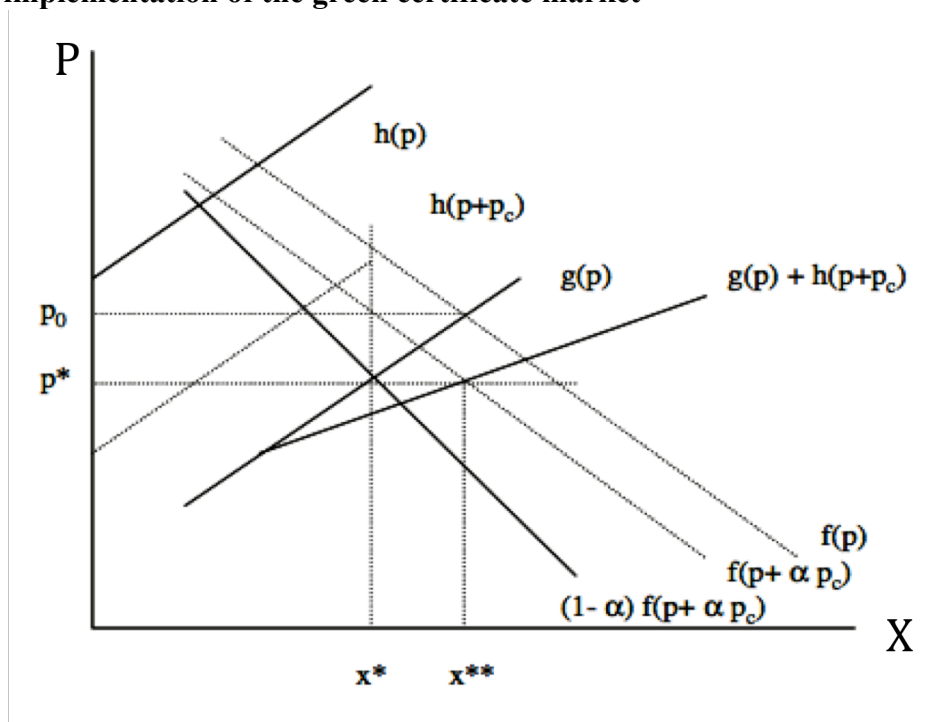
This part of the thesis will give attention to what the author perceive as the most outstanding arguments, concerns and issues that have been presented in the green certificate market debate. Analysis will be completed in order to understand the arguments, concerns and issues more clearly, to see what they are based on and whether they can be supported by economic theory.

5.1 Producer and end-user prices

“As a result of the green certificate market, the Nordic area will experience a power surplus that will lead to decreasing electricity prices”, is an expression from Prime Minister Stoltenberg (Glette, 2011). These are the same thoughts as Oil- and Energy Minister, Ola Borten Moe stated earlier this year. He said that by expanding the energy production in Norway and Sweden by the regulation of a green certificate market and at the same time hold back on the development of further energy cables to overseas countries, electricity prices would decrease and security of supply would increase (Dn.no). General economic theory supports Stoltenberg and Moe’s arguments. Implementation of a certificate market in Norway would mean that additional electricity sources would be developed. The production from new renewable sources would not replace already existing sources but come in addition to the current. Adding new supply to the market would shift the supply curve and lower the prices. Therefore, when supply of electricity in the energy market increases it is expected to cause a drop in the spot price, and thus also a lower consumer price if the decrease is larger than the certificate fee. How much the prices will decrease is dependent on the level of the quota. A higher purchaser commitment share equals not only increased development of new sources, additional electricity in the market and thus lower spot prices, but also increased certificate expenditures. Bye (2003) supports Stoltenberg and Moe’s argument and states that with increasing marginal costs in the supply and decreasing demand curves, it might lead to lower end-user prices on behalf of decreased profit for the green producers. The analysis of this argument is presented in figure 13¹¹.

¹¹ Based on Bye, T. 2003: On the Price and Volume Effects from Green Certificates in the Energy Market.

Figure 13: Price and volume effects of both traditional and green energy after the implementation of the green certificate market



Source: Bye, 2003

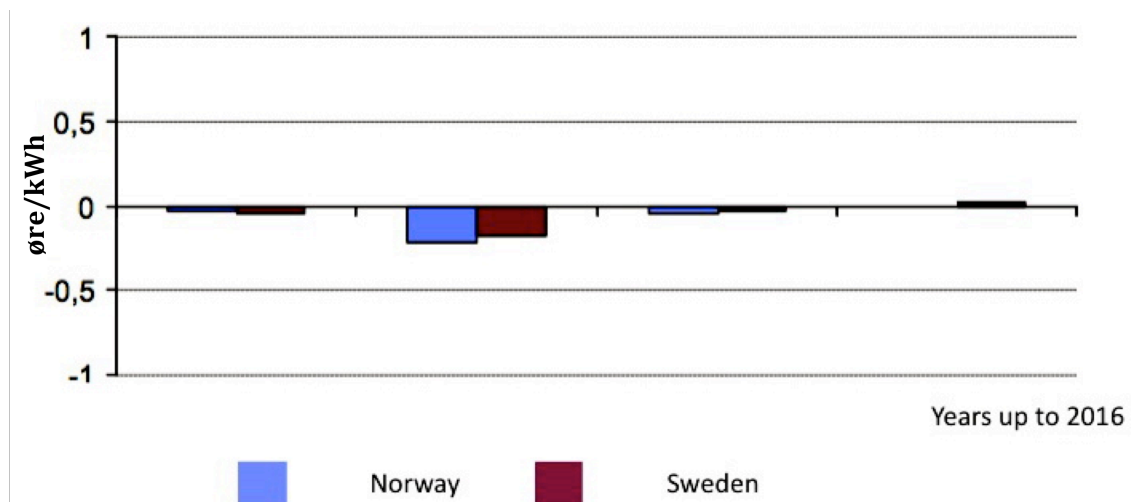
Initially, specific sources of green energy like wind and small-scale hydro $h(p)$ are too expensive to penetrate the market at an initial system price of p_0 . With an electricity price, p_0 a level of x^* green electricity will be consumed, as more expensive sources will fall out from the market. The green electricity production needs to increase to a proportion higher than x^* according to the RES-E Directive. However, the supply of new renewable technologies shifts to the right to $h(p+p_c)$ as the certificate market is being regulated and the certificate price, p_c , works as a subsidy for the green producers in the market. The green sources that are able to penetrate the market at a price p_0 is given by $g(p)$. Thus, the aggregate supply of green electricity is given by $g(p) + h(p+p_c)$ after the market regulation. The total required demand for green electricity imposed by the annual certificate quota is given by $f(p+\alpha p_c)$. The intersection between the aggregate supply curve $g(p) + h(p+p_c)$ and the aggregate demand curve $f(p+\alpha p_c)$ generates the new system price, p^* and the amount of green energy consumed, x^{**} . We see that the amount of green energy in the market has increased, while the electricity price has decreased due to the additional green supply. Since p^* is lower than p_0 , the spot price has decreased as a result of introducing a market for green certificates. If the total price (electricity price + certificate price) for the end-users actually is lower or higher than the initial electricity price depends on the certificate price. With a low

electricity price due to large additional supply from new renewable sources, the consumer price will be lower with a green market than without. Consumers would then benefit from the introduction of the market as the consumer surplus increases.

However, since the Nordic electricity market has been liberalised and is open for trade, these results are to large extent not applicable for Norway, as the analysis is based on an autarky market model. Norway is part of a larger joint Nordic electricity market where there are several small electricity producers and grid connections make trade possible. Borten Moe's statement of slowing down the development of further energy connections seems to be inconsistent with Statnett's development and operations, as additional export cables are being planned and constructed. "Skagerrak" with a capacity of 700 MW is under construction and will be ready to transport electricity from Norway to Denmark from 2014. "NORDLINK", an underwater cable from Norway to Germany with a capacity of 1000 MW is currently in the planning phase, the same is a cable between Norway and England that would connect the Nordic power market with the British (Statnett, 2011). Therefore, it is reasonable to believe that the initial increase in new renewable energy in Norway would only have a minor impact on the system price due to export and trade. The initial increased green production in Norway will be too small to influence the Nordic market prices significantly, as small changes in one country will be relatively modest in a larger market.

ECON Analyse (2004), on behalf of the Norwegian Ministry of Petroleum and Energy has conducted an analysis of the impacts on producer prices with a quota of 8 TWh in 2016. From the calculations made by the Norwegian energy authorities we see that the level of the actual quota in 2016 will be 7,33 TWh (10,8%), which is close the level ECON is using in their predictions. ECON's results of the forecasts of the wholesale prices are thus to a large extent relevant.

Figure 14: Changes in wholesale prices (NOK øre/KWh) with a quota of 8 TWh in 2016



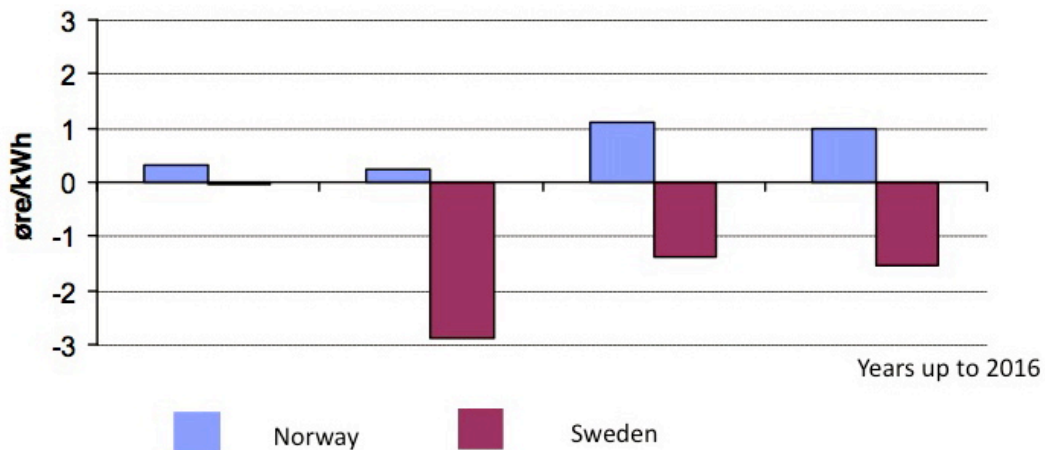
Source: ECON Analyse, 2004

As can be seen from the figure above, prices will start to decrease some years after the market has been regulated. This is due to the latency it takes from the market regulation to the new renewable sources are put into operation. As seen in previous chapters, the certificate market makes it profitable to invest in the development of electricity sources that otherwise would be too expensive to penetrate the market. Some investors are thus waiting to invest in new renewable energy sources until the certificate market is up and running. ECON thus expects a “rush” in projects being developed in the early stages of the market introduction. Many of these sources likely will not be ready to produce electricity until some time after the regulation. According to ECON, there will therefore be a period with sudden excess supply of electricity in the market, pressing the prices down. However, the changes in wholesale prices are marginal after the market has had some time to adjust to the sudden additional supply. New renewable sources will be developed in a smoother pace and prices will thus adjust back to the basic scenario. From ECON’s analysis we see that the impacts for the Swedish wholesale producers are expected to be approximately the same as for the Norwegian.

Consumer prices consist of more than just wholesale power prices. VAT, grid fees, electricity taxes and average certificate cost per KWh consumption also have to be taken into account. When the green certificate market will be in place from January 1st next year, electricity consumers will be facing an extra expenditure on top of the electricity price, as illustrated in figure 6. Consumer price of electricity will thus be equal to $P_0 + (\alpha \cdot Q_0) \cdot P_{GC} = P_T$, where α is the green quota share. Whether end-user

prices of electricity increase or decrease as a result of regulating the green certificate market is dependent on the price of the certificates, which in turn is dependent on the level of the annual quota, α and the system price. The prices for the end-users will increase by increasing quota, but the effect on consumer prices is low with a low quota. The following graph illustrates the changes in end-user prices for household customers in NOK øre/KWh with a quota of 8 TWh in 2016.

Figure 15: Changes in end-user prices with a quota of 8 TWh in 2016



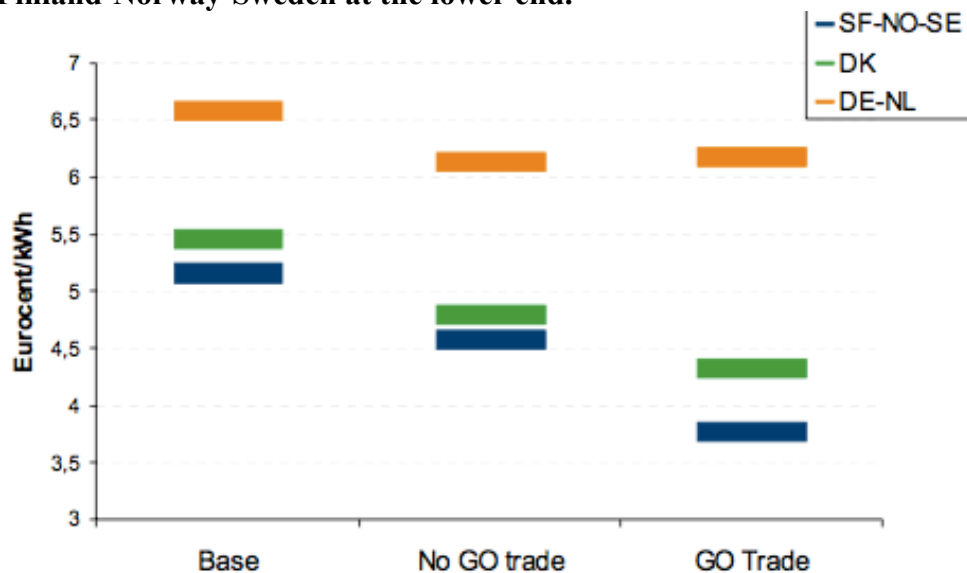
Source: ECON Analyse, 2004

The graph illustrates that there will be an increase in end-user prices for Norwegian consumers as a result of the market regulation. The increase is expected to be smaller in the first years after the market regulation than in the years that follows due to increasing annual quota. The increase will drop a little in the years close up to 2016 despite a higher quota. This is due to lower certificate prices, caused by an increasing supply of green energy as more sources are being developed over time. Swedish electricity consumers will on the other hand experience lower prices when Norway implements the green market. This is due to increased supply of certificates when Norway is joining the market. The results from ECON's analysis are that changes in wholesale prices will be marginal and that consumer prices will increase with the introduction of a green certificate market.

There is large uncertainty related to ECON's results. The analysis is old and at the time the study was conducted, the information about the ambitions and the structure of the joint market was not available. The analysis is thus performed with uncertainty of how much new renewable electricity that will be developed in Norway. The green certificate

market policy scheme is constructed so that additional new renewable energy sources will be developed over time, as it takes time from planning to operation for these technologies. When the supply of green energy is increasing in a faster pace than grids and cables are being expanded, the market balance would be changed and the excess supply of energy will push the electricity prices down. Nordic Energy Perspectives (NEP), an interdisciplinary Nordic energy research project, concludes that the Nordic electricity prices in 2020 will be significantly lower than before the market regulation, as future grid connections will not have sufficient capacity to export all the redundant electricity from the Nordic market. This is illustrated in figure 16.

Figure 16: Clear three-way division of price levels in 2020 with the hydro-area, Finland-Norway-Sweden at the lower end.



Source: Nordic Energy Perspectives, 2008

With increased RES-E in the Nordic countries (mainly Norway, Sweden and Finland), there would be a significant electricity surplus in this area. Due to insufficient grid and cable connections to the continental Europe, the spot prices would decrease. The price decreases in Germany and the Netherlands would be much smaller than for the Nordic countries, as the electricity market in Germany is significantly larger.

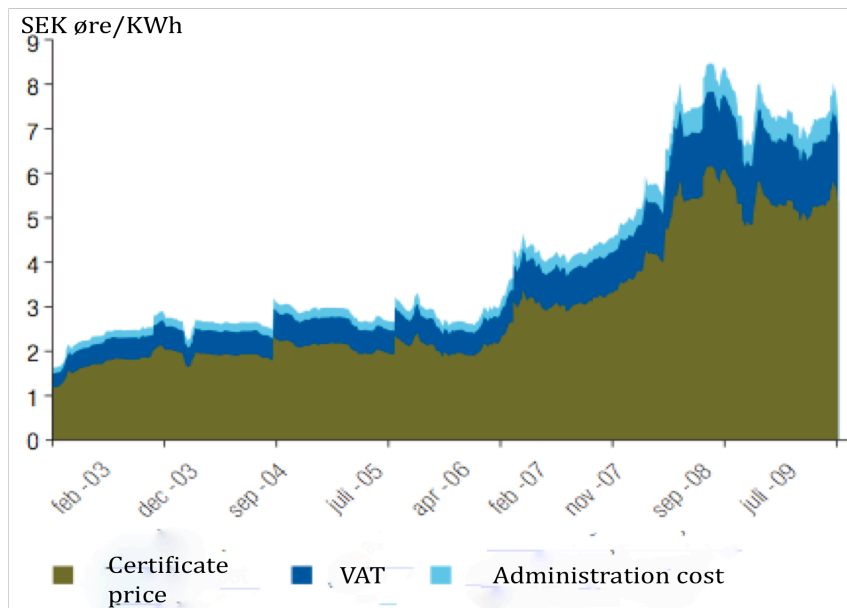
THEMA Consulting Group (2011) agrees with NEP's price forecasts and states that additional supply from new renewable energy sources of 10 TWh will add to existing electricity generation and decrease spot prices in Norway. According to the Norwegian Ministry of Petroleum and Energy's quota determination (Refer to table 1), additional green production will exceed 10 TWh by the end of 2018. If the forecasted increase in

green energy is correct, a decrease in spot price will be seen in the Nordic area in the medium to long run.

Despite ECON's analysis results being inconsistent with NEP and THEMA Consulting Group's findings, the regulation of a joint Swedish-Norwegian green certificate market would cause increased RES-E in both countries, which would press the spot prices down. The current power grid is currently close to reaching its limits. It is therefore expected that maintenance of the already existing transmission lines would be prioritized over further development of new grid connections and cables (Aadland, 2011). Nevertheless, how much the electricity prices decrease is dependent on the export quota, as well as weather and wind conditions. Dry years will decrease the renewable electricity supply and thus cause higher prices. It is therefore hard to make accurate forecasts of the changes in producer prices other than concluding with a price decrease.

With decreased producer prices, end-user prices will be affected. If the certificate price turns out to be larger than the gain from falling system price, the end-user price will increase. If the certificate price on the other hand turns out to be lower than the decrease in system price, consumer prices will decrease. Experiences from the Swedish green certificate market illustrates that the certificate expenditures for Swedish consumers has had an increasing trend from the introduction in 2003 to stagnation around 2008 (see figure 17). This is due to the fact that the certificate price is increasing with increased amount of green energy. Therefore, even with a decrease in wholesale prices, consumer prices might increase after the regulation of the green certificate market. However, given a Norwegian quota commitment of 3 percent in 2012 and a consumer's average annual electricity consumption of 20.000 KWh, the certificate expenditures would only add up to NOK 181,50 per year for this consumer¹². In other words, the system price does not have to decrease greatly in order for consumers to become better off during the first year of the market regulation. With a quota of 18,3 percent in 2020 on the other hand, the average consumer's certificate expenditures will rise to NOK 1107 per annum. According to NEP though, the spot prices would be at its lowest in 2020 (refer to figure 16), which might would make up for the increasing certificate cost. End-user prices are thus expected to decrease as a result of the green market regulation.

¹² The calculations are based on a certificate price of NOK 24,2 øre/KWh and 25 percent VAT.

Figure 17: Certificate price for consumers in SEK øre/KWh

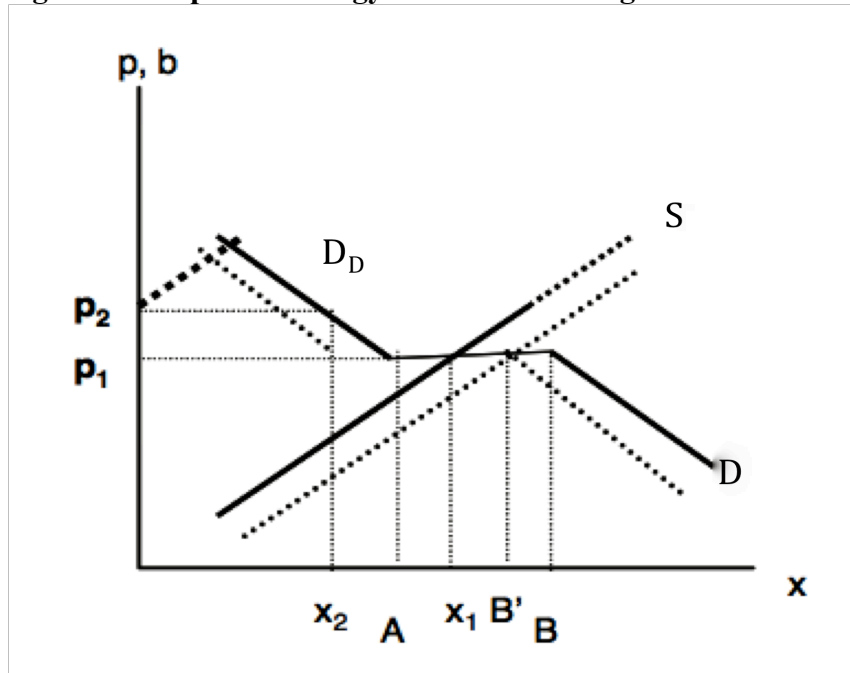
Source: Swedish Energy Agency, 2010

5.2 *Security of supply and the energy balance*

Import is a part of the supply side of the Norwegian economy, also when it comes to energy. Trade of electricity is fluent between grid-connected countries due to price variations, as a country would choose to import cheap electricity and export when domestic prices are higher. The Norwegian energy balance shows that Norway has been switching between being a net importer and a net exporter of energy during the last years. In 2010 Norway imported 7,5 TWh electricity, thus the net energy balance for Norway was negative. Increased share of renewable energy production would make Norway less dependent on imported energy to meet the demand, as the excess production from new renewable energy sources would come in addition to the current production.

The following analysis¹³ shows how Norway's export of electricity would increase with the introduction of a green certificate market. The analysis is conducted with the assumption of not fully utilized grid capacities. The wholesale prices would thus not be affected and consumer prices will increase (Bye et al, 2002). This causes the demand for electricity to decrease in the long run.

¹³ Based on Bye, T. 2003: On the Price and Volume Effects from Green Certificates in the Energy Market.

Figure 18: Export of energy and the effect of green certificates

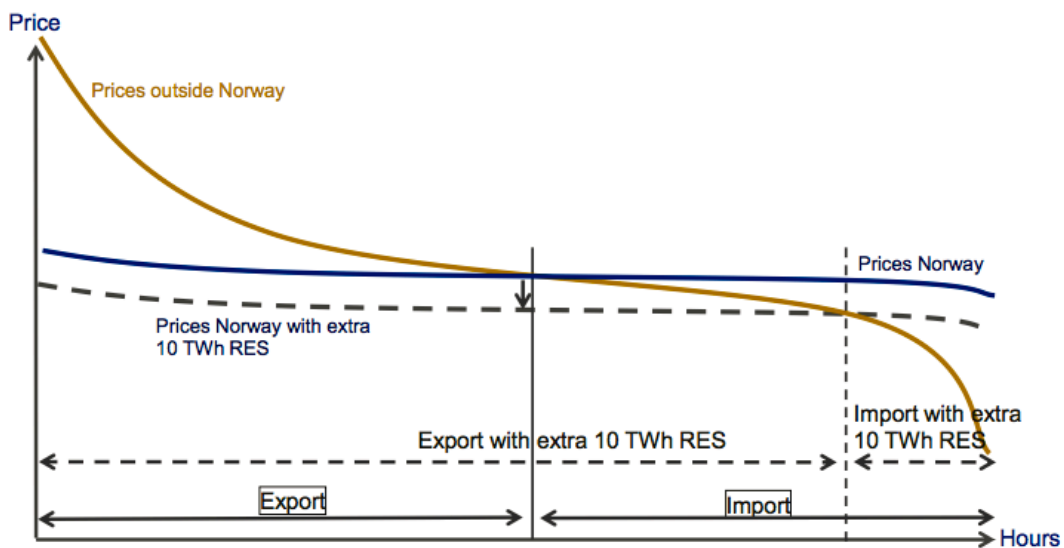
Source: Bye, 2003

With increased production from new renewable sources Norway would be a net exporting country at fixed prices. Domestic demand is given by the downward sloping curve D_D to the left of A, and exports are given by the infinitely elastic part of demand (the horizontal line between A and B) as long as transmission capacity is sufficient. The downward sloping part of demand, D, to the right of B is the remaining domestic demand when transmission capacity is exceeded. Supply is given by the normal upward continuous sloping curve, since exporting implies just domestic supply in this market. Demand is infinitely elastic around equilibrium (P_1, X_1) . Domestic demand is A, export is $(X_1 - A)$, while transmission capacity is $B - A$. The requirement for consumers to purchase green certificates is analogue to a purchase tax, and will cause an inward shift in the domestic demand curve (to the dashed line). The domestic certificate income on green production, which is analogue to a subsidy, will shift the domestic supply curve outwards (to the new dashed supply curve). The shifts in both domestic supply and demand curves do not change the energy price, P_1 as long as transmission capacity limits are not exceeded. The domestic purchaser price increases to P_2 , and domestic demand decreases to X_2 . Increased domestic supply and reduced domestic demand both contribute to increased exports by $(A - X_1) + (B' - X_1)$. Since the export increases, the market for green certificates has led to improved security of supply in Norway and increased the likelihood of being self-supplied with energy in a normal year. Green producers will benefit from increasing production, while the consumer surplus will

decrease as consumer prices are increasing with positive and increasing certificate price. This causes the domestic demand for energy to decrease and more of the electricity production could be exported. If however, the Norwegian production increases by a so large amount that the transport capacity in the grid is completely utilized, the market would be similar to an autarky as no further export is possible. Under autarky, consumer prices would decrease and there would be a redistribution of surplus from producers to the consumers, as the extra expenditures related to increased use of renewable energy would be paid by the producers in the conventional energy market (Bye et al, 2002).

Bye (2003) illustrated that the Norwegian electricity export would increase with the regulation of a certificate market. Additionally, the following analysis¹⁴ illustrates that the lower wholesale prices, the larger export. NEP and THEMA conclude that spot prices would be lowest when RES-E is highest. The export would thus be highest around 2020 when the increased RES-E in Norway have reached 13,2 TWh.

Figure 19: Illustration of effect of renewable investments on Nordic export



Source: THEMA Consulting Group, 2011

Figure 19 shows the price duration curves for Norway and for a thermal system “outside” Norway. A price duration curve sorts the prices of a year according to decreasing value. Since hydropower is flexible, the Norwegian price duration curve is

¹⁴ Based on THEMA Consulting Group in association with vivideconomics, THEMA Report 2011-2: Renewables and Emissions – The Effect of Norwegian Renewable Investments on Carbon Emissions

almost flat, whereas the thermal price duration curve is S-shaped with a large spread. When the thermal price is higher than the Norwegian price, we have export from Norway to the thermal market, and when prices in the thermal market are lower, we have import to Norway. The intersection between the price curves outside Norway and the price curves for Norway equals the level of the Norwegian export. We see that with lower prices in Norway export increases significantly. Thus, a green certificate market would increase export, but it is the wholesale prices in Norway relative to the wholesale prices outside Norway that determines the quantity of electricity exported.

Norwegian energy authorities have stated that one of their targets is to be self supplied with energy in a normal year. Increased RES-E increase the electricity surplus and since demand in the short run is assumed to be inelastic, export could increase as seen from the analysis in figure 18 and 19. Politicians like Jens Stoltenberg and lobbyist Frederic Hauge from the environmental NGO Bellona, have both in this context expressed their visions of Norway being “Europe’s green battery”. With increased renewable production as a result of the RES-E Directive, Norway could export more of its electricity production to other European countries that are dependent on a net import of energy. With its advantageous potential for increased production of renewable energy, Norway could function as a “battery” that supplies Europe with electricity. The idea is that water in certain reservoirs could be pumped up in higher storages if there is an over-supply of production when the windmills in Northern Europe is producing excessive supply of cheap electricity that is not needed elsewhere. Already today Norway is functioning as a “green battery” for Denmark. When the Danish wind power generation is low, Denmark is dependent on Norwegian hydropower to ensure security of electricity supply. Norwegian electricity producers, both traditional and green, would benefit from increased renewable energy production and closer grid connections with Sweden and the continental Europe as energy trade could be increased (Gullberg, 2011).

It is necessary to emphasize the idea of Norway as “Europe’s green battery” a little further. First of all, there is a substantial size difference between the Danish and the European market. The Danish energy market is small and thus Norwegian electricity production could contribute to ensure security of supply in this market. The German/European market is on the other hand relatively much larger, and thus the

Norwegian excess green supply would be too small to influence the market's power balance substantially. As we have seen in the price analysis in chapter 5-1, the additional green supply resulting from the regulation of the certificate market would only lead to small wholesale price changes in the Netherlands and Germany when certificates are tradable. Therefore, the influence additional Norwegian or Nordic green supply would have on a large European market would be small.

Even with increases RES-E in Norway, the transmission capacity from Norway to Europe would be insufficient to supply the market with substantial shares of additional electricity. Jørgen Kildahl, board management member in E.ON., expresses that if Norway has a vision of being a "green battery", grid connections and cables have to be developed at a much faster pace than today. Europe is not waiting for Norway, he states, if Norway is too slow the European market would find another solution (Nilsen, 2011). Capacity problems could thus be an obstacle for increased export of Norwegian electricity (Rosendahl, 2010).

5.3 Volatility in certificate prices

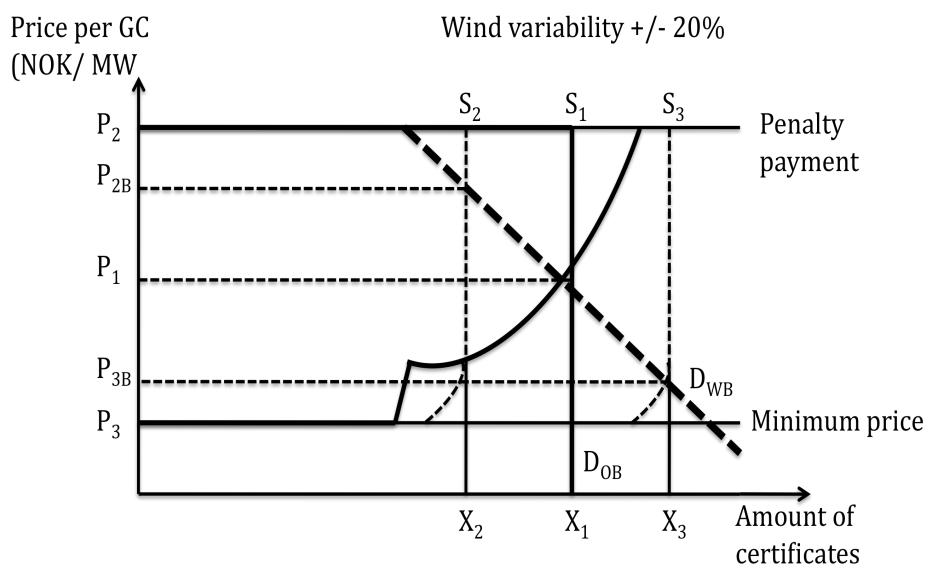
Criticism of the green certificate market often concern the varying prices a certificate market would cause in terms of electricity expenditures for the consumers and certificate income for the green producers. The combination of inelastic demand and significant volatility in electricity production from renewable technologies due to shifting weather conditions leads to volatile spot prices. Fluctuating energy production characterizes a whole range of renewable energy technologies, especially wind. In a green market with fixed demand, this might cause great volatility in the prices of the certificates. Additionally, these price changes may occur within a short period of time (Morthorst, 2000). Since new renewable energy technologies that will be assigned rights to receive certificates in Norway mostly involve small-scale hydro and wind power, variations in wind and rainfall will lead to volatilities in the certificates price as spot market prices influence the prices in the certificate market.

Another factor influencing the volatility in certificate prices is the level of the renewable quota. It is difficult to decide the share of renewable energy in the total energy consumption for every year, when the exact level of renewable energy production cannot be forecasted. The energy authorities' main objective is to set the

quota so that sufficient amount of RES-E is being produced. If the level of the quota were too low, the certificate prices would decrease so that development of new renewable technologies might not be ensured. If the level of the quota on the other hand were too high and the certificate price reached the maximum price, the optimal capacity development would be lower than the desired level. It would be a deficit in the certificate supply, causing the electricity consumers to pay the penalty for the unfulfilled share of renewable consumption even though they had no opportunity to get hold of more certificates. Thus, in order for the market to function like it is supposed to, the quota has to be as precise as possible for each specific year's renewable energy production.

Even though Norway's electricity production is particularly vulnerable to weather conditions, the volatility in the certificate prices could be significantly lowered with the opportunity of certificate banking. When the supply of electricity from renewable sources is high, the price of the certificates will decrease. This creates an opportunity for consumers or traders to buy more certificates than one needs and bank them to cover future obligations. This is possible because the certificates will be issued without an expiry date. The banking of certificates will create advantages for both consumers and producers of new renewable energy, as the certificate prices would become more stable. The banking situation is analysed in figure 20¹⁵.

Figure 20: How banking might reduce the price volatility in the green certificate market



Source: Morthorst, 2000

¹⁵ Based on Morthorst, P.E. (2000): The development of a green certificate market

The dashed line D_{WB} represents the situation where it is possible to buy additional certificates at a low price due to excess supply and bank them for upcoming years when the certificate prices might be higher, or the case where one uses some already banked certificates if the price of certificates is higher than expected. In relation to the wind variability problem, banking limits the price range to $P_{2B} - P_{3B}$, a considerably smaller range than in the case with no banking opportunity. Without banking the price range would be $P_2 - P_3$, which is the span from the maximum/penalty price to the minimum price. Certificate prices could vary between the maximum price and the minimum price within short period of time if certificate banking was not possible. Thus, with a narrower price range, volatility would decrease. The analysis shows that the opportunity to bank certificates creates a more stable certificate price, which is advantageous for both electricity consumers who have to pay for these certificates, and for new renewable energy producers who are dependent on the income from these certificates. A banking situation thus leads to higher predictability for both parties in terms of income for the green producers and electricity expenditure for the consumers. Potential investors of development of new renewable sources will also be able to make more accurate forecasts in the subsidies in terms of certificate income they can expect to receive.

Furthermore, in a situation with deficit of certificates (demand of certificates excess supply) and the certificates only are valid for one year, the excess demand will be converted to the penalty payment for the consumers. Since there are too few certificates on the market, it is impossible for the consumers to get hold of enough to fulfil their required share. With an external validity and the possibility of certificate banking, certificates banked in previous years might cover this excess demand and in this way moderate the irregular supply of certificates to the market. Again, the banking opportunity proves to ensure a more stable certificate price, which has been one of the strongest criticisms of the certificate market.

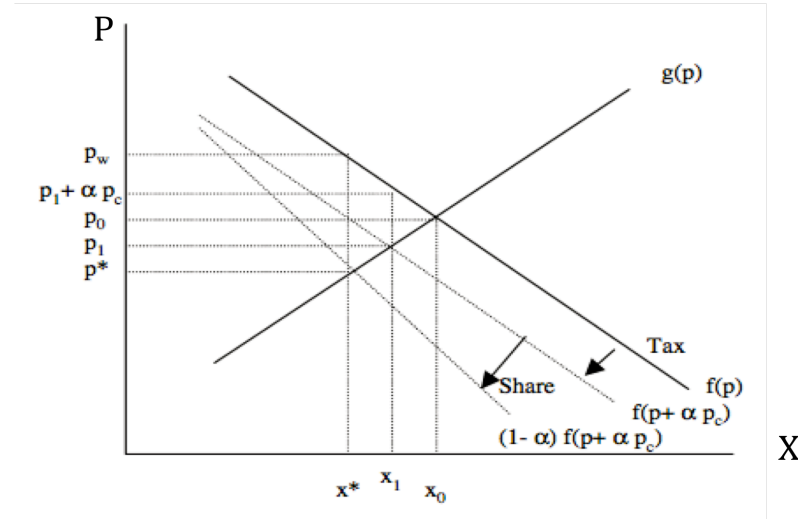
Another important aspect is that a larger European market, that might be the reality in the long run, would get rid of some of the volatility. With a larger European market there would be additional and diversified green suppliers. Weather- and wind conditions are significantly different in Norway and Sweden than in other European countries, and a larger market might also diversify the portfolio of new renewable

technologies. Thus, the volatility in the production output of the portfolio of new renewable technologies is likely to decrease as additional technologies and production areas are entering the market. In addition, the problem of determining an annual accurate quota will diminish when the market expands. Problems with covering the national quotas could be solved by import of certificates, while a surplus of certificates could be exported to countries that are lacking certificates. The national quota determination will thus get less complicated (Morthorst, 2000).

5.4 Impacts on CO₂-emissions

The regulation of a certificate market will lead to increased production of new renewable energy. Since consumers are obliged to buy a certain share of energy from these sources, domestic consumption of other traditional sources like large-scale hydro, heating oil, kerosene and liquefied petroleum gas (LPG) will decrease, unless the demand for these energy sources is totally inelastic (Bye, 2003). How much the demand for other energy sources will decrease depends on the consumers' total electricity consumption, how sensitive their consumption is to an increase in the energy prices and the renewable energy quota. If the government imposes a higher green energy share, the introduction of green certificates becomes a strain on the traditional energy market, and the traditional energy producers lose profit (Bye, 2003). Hence, green certificates contribute to an emission reduction of green house gases in Norway as the certificate market to some extent causes lower domestic consumption of fossil fuels (Bye and Hoel, 2009). The Zero Emission Resource Organisation (ZERO) states that Norwegian GHG emission could be reduced by 11 million tons with the implementation of the RES-E Directive (Lunde, 2010). The effect a green certificate market would have on the traditional energy market is illustrated below¹⁶.

¹⁶ Based on Bye, T. 2003: On the Price and Volume Effects from Green Certificates in the Energy Market.

Figure 21: Effects of green certificates in the traditional energy market

Source: Bye, 2003

Before the introduction of the green certificate market, equilibrium is given by (p_0, x_0) , where p_0 is the price for the traditional producers and x_0 is the amount of traditional energy in the market. The green certificate purchaser commitment will shift the demand curve inwards in two steps; the first step from $f(p)$ to $f(p + \alpha p_c)$. This step is related to the increased effective purchaser price, which is equivalent to the effect of introducing a tax on energy (αp_c). The inward shift would create a new equilibrium in (p_1, x_1) where the purchaser price equals $(p_1 + \alpha p_c)$. However, only a fraction $(1 - \alpha)$ of total demand may be satisfied by traditional energy. In the second step the demand curve twists downwards to the left, from $f(p + \alpha p_c)$ to $(1 - \alpha) f(p + \alpha p_c)$. This twist is a result of the commitment the consumers have to consume a share α of new renewable energy instead of traditional energy. The new equilibrium price and volume for the traditional energy producers is (p^*, x^*) , while the consumer price of traditional energy increases to P_w . The introduction of green energy will thus displace traditional energy, as the amount of energy from the traditional energy producers has decreased from x_0 to x^* (Bye, 2003).

Furthermore, there are currently carbon emissions taxes on heating oil and transportation in Norway. If the subsidy effect of new renewable energy is stronger than the effect of the current carbon taxes, consumer prices on electricity will decrease, as was being discussed in section 5.1. The analysis performed by NEP and THEMA Consulting stated that consumer prices most likely will decrease when the certificate market is being introduced, due to a decrease in the spot price in the medium to long run. The consumption of electricity will thus rise while the consumption of oil will

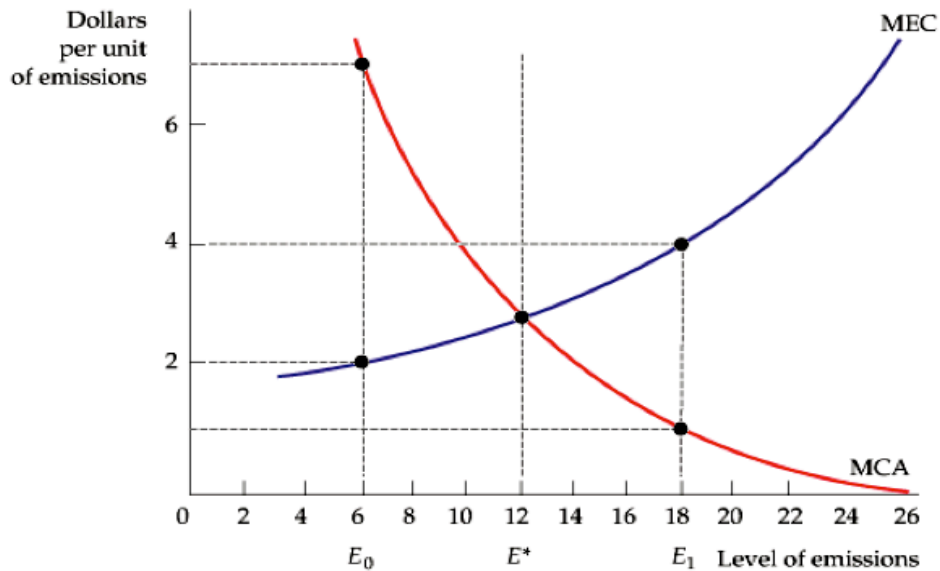
decrease. This will lead to lower emission of green house gases in Norway (Bye and Hoel, 2009). Håvard Lundberg, climate- and energy consultant at Bellona, agrees with the analysis above and states that the transition from fossil fuels to renewable energy is critical in order to reduce Norwegian GHG emissions (Bellona, 2011).

The above arguments include some statements that call for additional assessment. In figure 21 the analysis showed that when more green electricity enters the market, it would replace some of the traditional energy. That argument is correct, however only in an autarky. In an open market where trade is fluent, the excess energy production would be exported and thus not replace traditional production. The level of green house gas emissions in Norway would thus not decrease as long as transmission connections are sufficient. Furthermore, even with a decrease in end-user prices, it is less likely that it will lead to increased consumption of electricity that would replace the consumption of oil. Price-elasticity of energy consumption tends to be low due to little room for substitution. However, consumer prices of electricity might also increase in the long run when the quota and thus the certificate cost increase. This causes a decrease in the demand for electricity. Even with little room for substitution, some consumers might switch from electricity to an increasing use of fossil fuels for household heating. An increase in use of fossil fuels would lead to increasing green house gas emissions in Norway.

Additionally, increased renewable energy production in Norway will most likely not lead to reduced green house gas emissions in Europe. The European Union has decided on a cap on carbon emissions. Therefore, even though exported Norwegian green electricity might replace coal fired power generation in Denmark, the resulting excess quotas would be assigned other polluting industries, like for instance German concrete production. The amount of green house gas emissions within the European Union would thus be unaffected by a possible emission reduction in Norway (Bye and Hoel, 2009). The climate effect of a green certificate market is hence doubtful. With increased renewable energy, demand for carbon quotas will decrease and thus the prices on the carbon emissions will decrease. With a lower carbon tax, emissions will increase since polluters would choose to pay for emitting green house gases instead of abating. The following graph illustrates this issue. When price per unit of emissions decreases, the level of emission increases. An emissions price of 7 dollars per unit would for

instance generate an emission level of 6, while an emission price of 4 dollar per unit on the other hand would generate an emission level of 18.

Figure 22: Price per unit of emissions relative to level of emissions



Source: Pindyck and Rubinfeld, 2005

On the contrary, lower CO₂-prices are likely to induce a tighter emission cap in subsequent periods, as abatement becomes cheaper. Since the emission allowance cap is being tightened every year, it is not necessarily the case that the emission price will decrease when demand for the carbon quotas decreases. Furthermore, if the increased Norwegian exports replace more polluting energy sources abroad, European carbon emissions will be reduced. Hence, increased RES-E today implies reduced emissions in the medium to long term. If market participants expect tighter policies, banking will be increased, investment in fossil fuelled capacities postponed and R&D activities in clean technology stimulated. That means that short term emissions are likely to be reduced as well as it will be easier for regulators to tighten the emission cap (THEMA, 2011).

The increased development of new renewable energy sources caused by the market for green certificate will make it easier in the longer run to set stricter emission targets and requirements than it would be without the green certificate market. An increased reduction in carbon emissions in the following years is necessary in order for Norway to reach the target of 30 percent reduction compared to 1990 level. It is therefore important not to analyse the impacts of the green certificate within a static framework given the current climate targets, but rather analyse the market implications with the

focus on the opportunities it gives in the long run. A long view perspective is important in terms of reaching the ambitious targets of the climate policies Norway has decided on if we are to avoid the most severe consequences of global warming (Alfsen, 2009).

Moreover, a fee on electrical consumption, as the green certificates impose, creates a greater awareness of the link between energy consumption and climate change. By placing the responsibility of financing renewable energy sources over to the consumers, their awareness of the climate challenges might increase, and many consumers will thus find it fair to include the externality costs of their energy consumption in addition to the real costs. The increasing focus on combating climate change will thus have a broader support among the energy consumers, as they are paying extra to contribute to lower emissions (Morthorst, 2000).

40 percent of the energy consumption is exempted from participating in the certificate market. Hagem and Rosendahl (2011) argue that energy intensive industry will experience lower electricity prices as a result of the market regulation, which will lead to increased activity and thus an increase in emissions. As seen in chapter 5.1, wholesale prices would decrease after the regulation of the green certificate market, if not transmission capacities are being improved and developed. Additionally, if the market participants do not expect regulations to be tightened in the future, as the carbon quota prices decrease, the effect on emissions via banking, investments and R&D activities will be weaker and in the worst-case negative, leading to increase in GHG emissions. Furthermore, as stated earlier, increased renewable investments in Norway would be marginal in a European and global context. It might be naive to believe that increased RES-E in Norway and Sweden will have such a large impact on the carbon prices in the European Union that it induces a tightening of the carbon cap. Nevertheless, all increases in renewable investments are marginal, and since every European Union member country has to stimulate increasing RES-E according to the Directive, the total effect of aggregate increased RES investments might be significant in the climate policy and lead to a tighter emissions standard in the future (THEMA, 2011). After all, the future aim is to expand the Swedish-Norwegian certificate market over time so that more countries are included in the scheme. The joint marginal emission reductions of the countries included in the certificate market measure would then be significant.

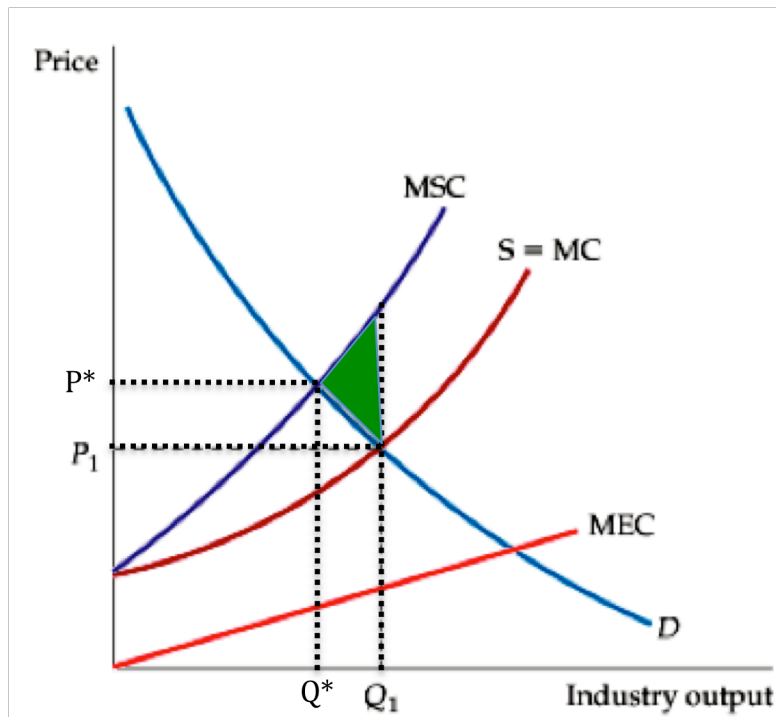
5.5 *Cost-efficiency*

Today's subsidy scheme for renewable energy is constructed so that different projects are being assigned funds after an application process. The funding organ responsible for assigning the different projects with subsidies has diminutive information about what are the best projects – i.e. how much green energy that could be produced given the amount of the subsidies relatively to the amount of green production that have been promised to be delivered in the application prospect. The public sector has limited information, and many investors could take advantage of this and over-estimate their need for governmental funding. Investors may overestimate the capacity of their power plant and apply for larger funding than they actually need in order to make their projects as profitable as possible. In an article published by “Teknisk Ukeblad”, Nilsen and Lie (2011) revealed that Norwegian wind farms yearly produce 25 percent less electricity than what the investors had promised in their application for development subsidies. Norwea, an interest and lobbying organization working for promoting Norwegian renewable energy, admits that the potential for wind power capacity in Norway has been overestimated. President of the Norwegian Society for the Conservation of Nature, Lars Haltbrekken, is thus sceptical to the current wind power subsidy scheme and says that large nature intervention that only leads to minor energy production is inefficient management of the resources (Nilsen and Lie, 2011). In a certificate scheme however, the market itself would carry the costs of poor projects and it would be a strong incentive for cost-efficiency. If the certificate market works as it is supposed to and negative externalities are being internalised in the market, there would be no dead weight loss, as is the case for the current scheme of governmental subsidies (Bye, Greaker and Rosendahl, 2002).

Economists like Hagem and Rosendahl (Samfunnsøkonomen nr. 3 2011) have, on the contrary, criticised the green certificate measure of not being an efficient way of reducing GHG emissions. Economic efficiency is defined as the maximization of aggregate consumer and producer surplus (Pindyck and Rubinfeld, 2005). Economics of climate change and environmental economics state that in order to gain cost-efficiency in increasing one specific good, i.e. new renewable energy production, the other good (fossil fuels) has to be taxed instead of subsidising the desired good. A certificate market would however, subsidise green electricity instead of including the marginal external cost of fossil fuels in the cost function. To subsidise a “correct” price

determined by the market while leaving the negative externalities caused by polluting goods untaxed is an “incorrect” price, as marginal external costs are not included. It is also in conflict with general economic terms (Haugneland, 2011). An illustration of efficiency gains and losses arising as a result of taxing polluting goods, and as result of subsidising green energy production will be compared in the analysis in figure 23 and 24 below.

Figure 23: Efficiency gain when negative externalities of polluting goods are included in the supply



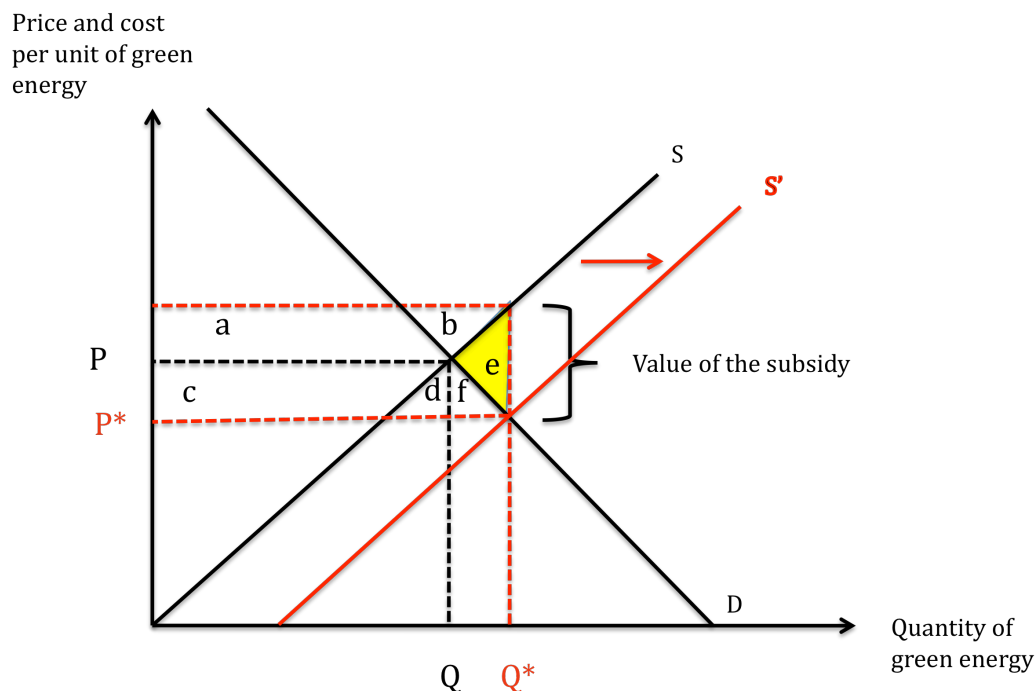
Source: Pindyck and Rubinfeld, 2005

Figure 23 shows the market demand and supply curves, where $S=MC$. The intersection between these curves gives us the price, P_1 and the output, Q_1 of polluting goods. The external cost curve (MEC) represents the increase in harm to society as the polluting industry increases its output by one unit. In the “business-as-usual” scenario, these costs are not included in the industry’s supply curve. From a social point of view, the polluting industry thus produces too much output which causes pollution. The efficient level of output is hence the level at which the price of the polluting good is equal to the marginal social cost of production. Marginal social cost of production is the sum of the production costs and the marginal external costs ($MC + MEC$). When putting a tax on polluting goods, marginal external costs are being included in the cost function of the production. We then get a new supply curve, illustrated by the MSC curve. The intersection between the marginal social cost curve and the demand curve gives us the

new equilibrium. The quantity of polluting goods will then decrease to Q^* and the price of polluting goods will increase to P^* . Due to excess production of polluting goods in the “business-as-usual” scenario, an economic inefficiency equal to the green area is present. By imposing a tax on polluting goods due to the negative externalities their production creates, this economic inefficiency disappears. Tax on polluting goods is thus an efficient policy.

A subsidy to producers of new renewable energy would on the other hand be less cost-efficient, as illustrated in the figure 24. The value of the subsidy payment is given by the area $a+b+c+d+e+f$. After the introduction of the subsidy, the change in consumer surplus is $c+d+f$ and the change in producer surplus is $a+b$. Net benefits equal change in consumer surplus plus change in producer surplus minus subsidy payment = $(c,d,f) + (a,b) - (a,b,c,d,e,f) = e$ which is a dead weight loss. There is hence a net welfare loss related to introducing the green certificate market in general economic terms. The yellow area indicates the inefficiency.

Figure 24: Efficiency loss resulting from subsidising green energy production



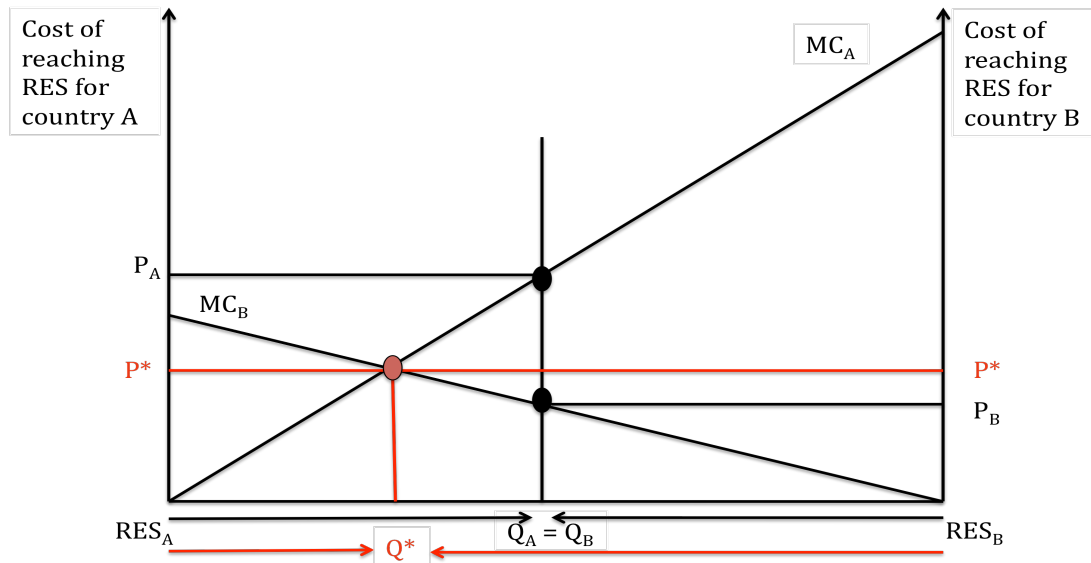
This example illustrates how the desired outcome of increased new renewable energy would be reached in a more cost-efficient way with a tax on polluting goods than with a subsidy in terms of green certificates. However, the case with introducing a green certificate market is more complex than what the above analysis illustrates. As the

following part explains, the outcomes of the cost-benefit analysis changes when one takes the RES-E Directive into account.

In the report “1/2005 Pliktige elsertifikater”, Golombek and Hoel argue that a green certificate market would be a cost-efficient tool if Norway implements the European Union’s RES-E Directive. By using the numerical model LIBEMOD (Liberalization Model of the European Energy Markets) Golombek and Hoel conclude that a market for green certificate is a cost-efficient measure for reaching the renewable target. The two economists have analysed the scenario where Norway and Sweden have a joint certificate market and where the quota is set to 5, 10 or 20 percent. Their calculations prove that even with a quota as low as 5 percent, investments in wind power in Norway would be profitable. Furthermore, Norway would always have a positive net present value from the certificates in a joint market with Sweden (Golombek and Hoel, 2005). Bye (2003) supports the argument that green certificates is a cost-efficient tool; “An advantage of this green certificate instrument over a simple price and standard investment subsidy instrument is that the certificate market will contribute to a cost-efficient solution in the energy market under the green energy production share constraint. The green commitment share and the definition of green technologies is a governmental issue”. Del Rio (2005) agrees with Golombek and Hoel’s arguments. He states that the RES-E Directive targets could be reached at a much lower cost in a joint national support scheme combined with tradable green certificates. The following analysis¹⁷ illustrates why that is the case.

¹⁷ Based on Del Rio, P. (2005): A European-wide harmonised tradable green certificate scheme for renewable electricity: is it really so beneficial

Figure 25: Cost of reaching the RES-E target for the two countries in autarky and in a joint market



Source: own figure

Figure 25 is a two panel diagram showing the RES marginal cost curves for two countries, Sweden and Norway, referred to as respectively country A and country B. When the two countries aim to reach the RES-E individually $Q_A = Q_B$, country A would have a much higher marginal cost (MC_A) in reaching the target than country B ($MC_A > MC_B$). The cost of reaching the RES-E target for country A is thus P_A , which represents the certificate price in country A. The cost for reaching the target for country B is P_B , which is the certificate price in country B. Even though both countries have the same level of ambition in the targets, country A would have a higher certificate price than country B due to higher marginal costs.

If the two countries agreed on a harmonization of their policy support schemes in combination with tradable green certificates, the same amount of $Q_A + Q_B$ could be reached but at a lower cost. Cost-efficiency will be gained when the two countries' marginal cost curves ($MC_A = MC_B$) intersects, indicated by the red point. In a joint certificate market where both countries have the same RES-E target, the certificate price would be P^* and the RES production for both countries would be Q^* . With a certificate price of P^* the expensive production of RES-E in country A would be reduced, the cheap production in country B would increase, and the aggregate compliance cost would decrease. Trade would then be driven by the possible gains for both countries with different marginal cost curves. Since country A has a higher

marginal cost curve for producing RES-E, the country will in a joint market have the opportunity to save costs by buying certificates from country B in order to reach its RES-E target instead of producing the total amount of RES-E themselves. Country B with lower marginal costs will on the other hand produce more RES-E and sell their excessive certificates to country A. Thus, the joint certificate market between Norway and Sweden would be cost-efficient and a win-win situation for both countries with the implementation of the RES-E Directive.

This analysis illustrates that both countries individually would be better off if harmonization of support schemes combined with a TGC system was implemented. Country B would obtain additional revenues while country A would save costs. Not only would individual countries be better off, but also the overall target (i.e., RES-E Directive target) would be achieved at a lower cost. The reason harmonization with trade would be cost-efficient is that the equimarginal principle¹⁸ is accomplished.

Söderholm (2008) has emphasised one of the major benefits of an integrated green certificate market from a cost-effectiveness point of view. A joint certificate market with Sweden could mean that consumers in Sweden for instance pay for the development of renewable power projects in Norway. That is because the scheme is technologically neutral, i.e. the cheapest sources would be developed first, regardless of where they are located. If for instance wind power is cheaper in Norway than in Sweden, the integration applies that the certificate fee paid by Swedish electricity consumers is reallocated from Swedish to Norwegian owners of wind power plants. Cost-efficiency will be gained when investments are made where they are cheapest and the aggregate cost of achieving the quota obligation is minimized. Also by expanding the market to include additional countries, the economic efficiency of the scheme would increase. A country with available green electricity or with potential to expand their green production to relatively low costs, could sell certificates to another country where renewable energy is more expensive. The buyer of the electricity could in this way fulfil part of its required quota, while green producers would have the possibility to finance even more of their production and investments in renewable energy. The result would be the same amount of renewable energy, but to a lower total cost (Söderholm, 2008).

¹⁸ Equimarginal Principle: The point at which consumption or production minimizes spending per unit consumed or produced. In environmental economics, the point at which desired emissions reductions for different firms are achieved at the minimum possible cost.

In a larger European market a few countries may take the lead and introduce a multilateral joint support scheme. The more countries that participate, the less sensitive the integrated system becomes to policy changes in one of the countries, which could affect the market mechanisms and thus the prices of the certificates.

A joint green certificate market with Sweden will on the other side make it more difficult to control how much green electricity that is being produced domestically. This will again make it hard to determine if Norway has reach the RES-E Directive within 2020. Additionally, the scheme does not comply with the required demand for reaching cost-efficiency in a renewable target according to Hagem and Rosendahl (2011), a statement contrary to the analysis from Golombek and Hoel presented above. One example is that a market for green certificates only includes new renewable energy, while the RES-E Directive on the other hand sets requirements to the total share of renewable energy in the consumption. Thus, the scheme as it currently is designed, does not give strong enough incentives to reduce the energy consumption. Another problem is that the market only includes the consumption of electricity while the RES-E Directive emphasises all energy consumption. The green certificate market will thus not give incentives to decrease consumption of other energy sources than electricity, if not the price of electricity decreases relative to other energy sources. Furthermore, green certificates will be an unsuitable measure for the Norwegian energy system. Norway has little electricity production based on non-renewable sources. The situation in the European Union however is completely different, as most of the energy consumption originates from fossil fuels. Thus, it might seem like a green certificate market would be more appropriate in the European market than in the Norwegian.

The aim of the market is to increase the production of renewable energy in Norway. It takes time to develop new renewable sources as the planning and implementation stages normally takes many years. Other measures, such as increased direct subsidies or feed-in tariffs, could ensure a steeper development rate than what the market for green certificates would do. However, the latency will increase the stability of renewable energy and make the long-term determination of the renewable quotas even more important (Morthorst, 2000).

A green certificate market might in certain cases increase the expenditures for the government. If the market collapses due to disruptions in the market mechanisms, the price will either jump to the maximum price or fall to the minimum price. If the price reaches the minimum payment, the government would have to subsidize the difference in order to ensure that additional new renewable sources are being developed.

5.6 Research and development

Today's subsidy scheme requires that the government must evaluate every project that is applying for subsidies through Enova SF. Thus, each project that applies for subsidy support has to be of a certain size and have a satisfyingly large production capacity in order to justify all the costs related to application and case handling (Gran, 2004). This causes smaller renewable energy projects to fall out from the subsidy scheme and being left undeveloped due to lack of funds.

The proposed green certificate market will on the other hand lead to a market based technology selection and investment allocation. This will most likely contribute to research and improvements of a mixture of renewable technologies. Improved technology is essential for developing various and innovative renewable energy sources, but has come to halt due to the higher expenditures related to these premature technologies than for the cheaper well-established hydropower. Increased production of a specific renewable energy source strengthens the knowledge, both in the respective industry and in other similar domestic industries, and lowers the costs. This causes the energy production to be more efficient also in other industries, as there will be positive externalities resulting from increased production (Golombek and Hoel, 2005). An increase in knowledge and technology improvements is important if we should be able to reduce emission of green house gases by a large amount in the future (Bye and Hoel, 2009) and if the world aims to be less dependent on energy from fossil fuels in the coming decades.

Since the green certificate market implementation will lead to a steeper development curve of technologies like wind energy, the demand for components for building wind turbines and other new renewable technologies will increase. Producers of renewable energy technologies would thus gain from the introduction of a green certificate market (Bye and Hoel, 2009). Increased knowledge and expertise in the technology of renewable energy development could make Norway gain competitive advantages within

the clean technology industry. Investors and companies' focus on sustainable investments are globally increasing due to climate targets and energy crises, thus the demand for renewable technologies is expected to increase. Because of the green certificate market, Norway has a chance to become a pioneer in development of clean technology.

The status quo is however not so simple. The third largest oil field in the Norwegian oil history, Aldous, was recently (2011) discovered on Norwegian shelf. Experts assume Aldous could contain as much as 3,3 billion barrels of oil. That indicates that the Norwegian petroleum industry would demand a large share of professionals in Norway. The Norwegian Oil Industry Association (OLF) predicts that approximately NOK723 billion would be invested on the Norwegian shelf during the four upcoming years as long as the oil price remains high (Øyehaug and Gaasemyr, 2011). This would mean a large increase in activity level for the oil service firms that supply oil companies with goods and services. Some of these companies might actually experience that they are not able to cover the increased demand from the oil sector. When the activity level increases, employment normally expands. Within the oil sector, the demand for engineers would be especially high. FMC Technologies, a provider of technology solutions to the energy industry, on average employs 50 workers every month, most of them engineers, and will hire approximately 400 to 600 new employees during 2012 (Ree and Helgesen, 2011). However, in order to develop clean technology in the renewable energy sector, engineers are needed to stimulate innovation and new ideas. Since the petroleum industry is relatively much more competitive when it comes to salaries and payments for the employees than the renewable sector tend to be, the petroleum sector might seem more attractive for the main share of the Norwegian engineers. The availability of engineers who can contribute to R&D in the renewable energy sector would therefore decrease and research and development of new technologies might come to halt if not imported labour could make up for the petroleum sector's dominating position.

As stated earlier, a certificate market would mean that the most cost-efficient technologies would be developed first, where wind power and small-scale hydro would be the dominating new renewable energy sources in Norway. This is despite the fact that there would be more learning effects related to electricity production from immature technologies like tide- and wave energy than for well-known technologies

like hydro. Thus, in many cases it will lead to greater innovation and technology improvements if the funding of research, development and demonstration was targeted new technologies instead of subsidising small-scale hydro where the technology already is mature (Hagem and Rosendahl, 2011). Furthermore, in a situation where the investment resources are becoming scarce, which could be the case if there is a significant expansion of renewable capacity development, renewable energy technologies might become substitutes for each other instead of complementary technologies for promoting various new renewable energies. The need for complementary technologies is especially important in the long run if green house gases are to be reduced.

Green certificates are one type of deployment subsidies, which means that they promote development of certain technologies (the ones the government has decided are green technologies), while taken the focus away from other technologies that are not seen as green. Thus, green certificates lead to no incentive for the single producer to invest in R&D if the results of the R&D will be available to all the producers in the same industry. R&D subsidies, not green certificate subsidies, will lead to increased focus on technology development and cost reductions targeted directly. Premature and unknown technologies could thus be subsidised more accurately, as certain shares of the funds could be assigned to specific technologies. Through a green market only the most efficient technologies would be developed while others would lack behind. This creates a “lock-in” of relatively efficient green technologies and a “lock-out” of immature green technologies. In this case, the green certificate market comes short and could prevent development of promising technologies with high learning curves, which yet is not as efficient as other green technologies. It could thus be necessary to engage in parallel subsidising schemes in order to ensure a diversification of the technology portfolio and to avoid a “lock-out” of promising technologies. Technology specific R&D funds such as investment subsidies and licences could be implemented parallel with the green market. However, interference might disturb the price determinations in the green certificate market and cause the market not to function as it is supposed to (Bye, Greaker and Rosendahl, 2002).

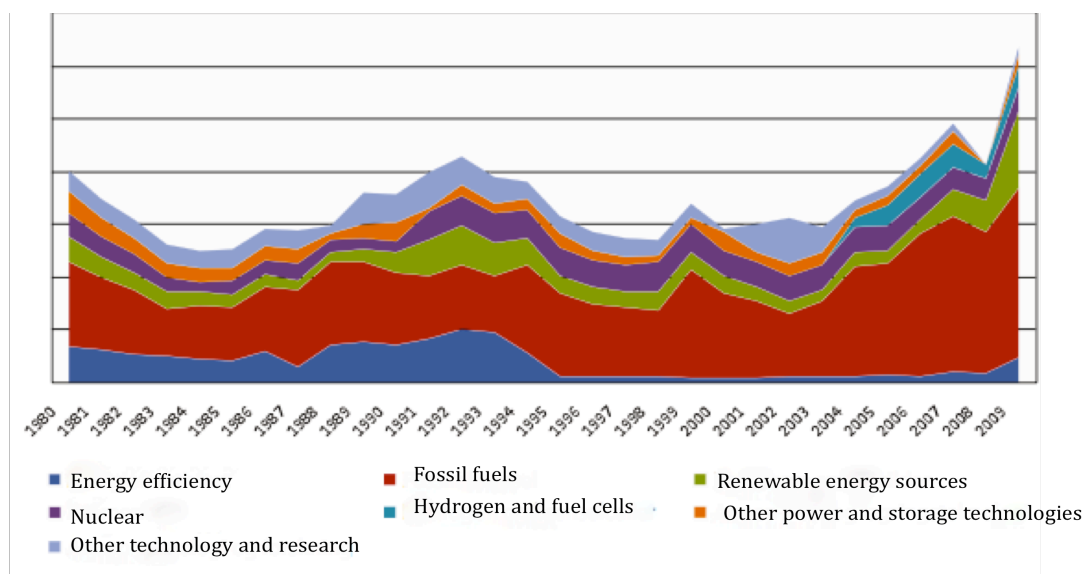
Additionally, prices on carbon quotas will decrease with a regulation of the green certificate market. Lower prices on carbon emissions will make it less attractive to engage in research and development of new energy technologies. Further development

and improvement of relatively new technologies like energy conservation or CCS is important if green house gas emissions are to be reduced at a lower price in the future, and in order to make it easier for other countries to consent to stricter carbon emission agreements. As a paradox, a subsidy scheme like green certificates may cause difficulties in increasing the R&D activities within carbon abating projects and may prevent stricter climate policies of being introduced after 2020 (Bye and Hoel, 2009).

5.7 Predictability of investment subsidies

Today's scheme where the research Council of Norway, Innovation Norway, Enova SF and other governmental organisations are the responsible organs of subsidising development of renewable energy strongly relies on political will. The funding structure becomes complex, and from one political period to another the parties responsible for assigning the organisations with funds that are to be used for subsidising renewable energy projects varies. Politicians and ministers from respective parties have different views and opinions about the importance of the development of new renewable energy technologies. This is influencing the level of the funds granted from the government to the funding organs and thus also impacts how much renewable energy is being developed and how fast. It leads to unpredictability in the subsidies of renewable energy and hence slows down the development. The graph in figure 26 below provides an overview of research-, development- and demonstration budgets for energy purposes in Norway from 1980 to 2009.

Figure 26: Norwegian research-, development- and demonstration budgets for energy purposes 1980-2009 in billion Euros



Source: Klitkou, 2011

We see that the research related subsidies for renewable energy have been significantly smaller than the subsidies for fossil fuels during the whole period. Public subsidies for energy purposes have largely been assigned fossil fuels, while the funding for hydropower has stagnated and led to a decline in the hydropower knowledge and competence in the Norwegian R&D environment (Klitkou, 2011).

Even though public funds for supporting renewable energies like solar and wind have grown rapidly during the last years, these subsidies may change with shifting political governance. As times goes by and the political situation in Norway changes, it may happen that the subsidies of renewable energy are being cut off significantly. As the size of the subsidies is considerably variable, the potential investors' interest in the development of renewable energy has been decreasing due to low predictability in subsidies (Gran, 2004). A market for green certificates, where the subsidies are paid directly from the consumers, might increase the predictability in development subsidies. However, since the price of the certificate varies with volatility in productions, the additional income for the green producers is being affected. As have been illustrated above, heavy rainfall and wind will lead to decreasing certificate prices while dry years with modest wind will lead to the opposite. Nevertheless, the analysis of certificate banking has shown that the volatility in certificate price, and thus also the income for the producers, would decrease when certificates are issued without a due date. This increases the predictability of income for the new renewable producers and might lead to more renewable projects being put into operation.

Experiences from Sweden show that after a slow start the Swedish support system is now starting to bear fruit, and some leading international wind power developers have entered the Swedish market (Global Wind Energy Council, 2009). The table below presents a comparison of wind energy production in Sweden and Norway as of the end of 2010.

Table 3: Wind power capacity and growth rate Norway and Sweden, 2010

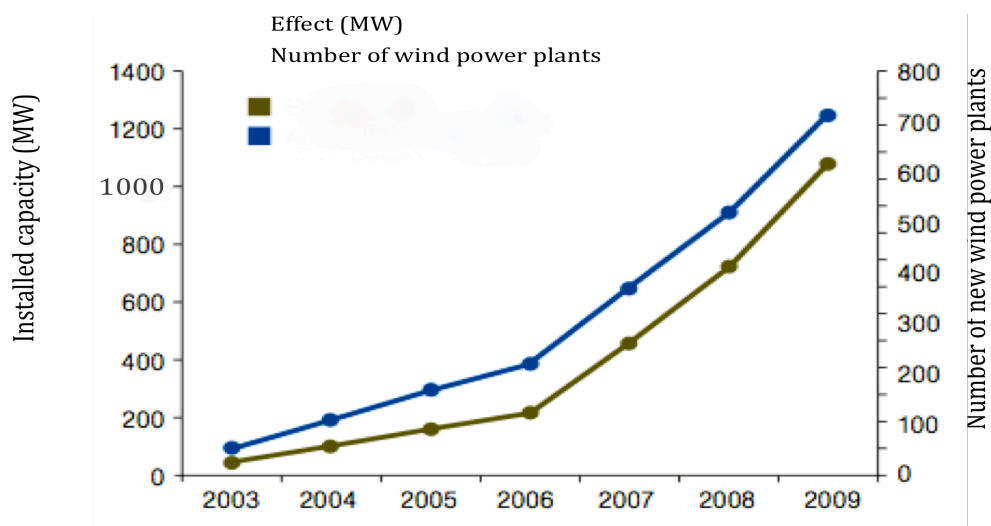
	Sweden	Norway
Installed capacity (2010)	2163 MW	441 MW
Growth rate	28%	2%

Source: Global Wind Energy Council, 2009

As the table presents, the differences in installed wind capacity and growth rate in the wind industry is significantly larger in Sweden than in Norway. One should be careful to draw the conclusion that the Swedish green certificate market is the only reason for

the increased wind power development. However, it is reasonable to believe the market should have some of the honour, as it has attracted more foreign investors. The graph in figure 27 below shows that there has been an increase in the amount of wind power plants in Sweden after the introduction of the green certificate market in 2003.

Figure 27: Total amount of new wind power plants in Sweden and their installed capacity



Source: Swedish Energy Agency, 2010

Søderholm (2008) on the other hand raises the question of whether political risk actually will decrease with the establishment of a green certificate market. The presence of two countries implies two different political wills when it comes to environmental and energy issues and thus doubles the complexity. Søderholm states that there exist a large number of interest groups, thereby politicians, that often have more specific expectations about the outcome of the system. Specific lobby groups in turn often represent the different energy technologies. When taking that into account, the likelihood of tensions between different interests (e.g. some cheering for wind power, others for bio-fuels) will arise and changes in the scheme may be initiated. An extended market may imply a larger number of potential conflicts about the design and outcomes of the system. Such changes due to pressure from different interests will cause a decrease in predictability of the subsidies, which might affect the development of new projects. However, all changes must not only be agreed on at a nationally basis, but two countries have to agree on any measures that would affect the scheme. Additionally, if conflicts occur one of the countries may want to abolish the joint market. Sweden and Norway have had different strategies in their energy and environmental policies.

Sweden has had a strong focus on renewable energy sources, while Norway has mainly given more emphasis on the use of natural gas and CCS.

Nevertheless, Söderholm concludes that the size of the political risk probably will not increase as the number of countries participating in the scheme increases, e.g. with a larger European market. However, changes in one country may have profound impacts on the functioning of the market as a whole, and a low participation rate (like for the bilateral market between Sweden and Norway) makes the market more sensitive to policy changes. Since the joint green certificate market between Norway and Sweden currently only includes these two countries, the political risk facing investors will increase when Norway enters the market as of January 2012. The increased risk for investors might affect the development of new renewable energy projects, and the same development rate as has been seen in the Swedish wind power industry might not be the reality for Norway. President for the association for small-scale hydro, Henrik Glette, emphasize how important large markets are for the predictability of investment subsidies. He claims RES investments would come to halt if the government prevents a further development of overseas cable and grid connections (Tekna, 2011).

6 Conclusion

The implementation of a joint green certificate market with Sweden will lead to consequences for Norway. As the regulation of the certificate market will lead to increased development of new renewable energy sources, spot prices on electricity will decrease. However, since Norway is part of a larger international electricity market, the exact decrease in system price is hard to forecast and analysis conclude the wholesale price reduction could be either marginal due to increased export, or substantial as several additional sources are being developed in the medium to long run. Nevertheless, due to insufficient transmission grids and cables, increased RES-E in Norway and Sweden will lead to lower power prices. The decrease in spot prices affects the consumer prices. Even with the additional certificate cost on top of the consumers' electricity usage cost, consumer prices are likely to decrease. The fall in the system price is expected to be larger than the additional end-user certificate cost.

The security of supply increases when further electricity sources are being developed. Norway would then be less dependent on imported energy and instead increase its export share. However, the increased electricity capacity is not large enough to function as a "green battery" for Europe. The European market is too large and insufficiency in transmission cables cause further obstacles for exporting Norwegian electricity to the European continent. Due to capacity problems in the current power grid, further development of new connections is likely to be given lower priority.

Volatility of the certificate prices can be reduced with certificate banking. When certificates can be saved for later periods, the certificate price range decreases relative to the base scenario. Certificate banking is thus an efficient measure to avoid "maximum to minimum" volatility in certificate prices within short time.

There is assumed that the implementation of a green certificate market would not lead to significant CO₂-emission reductions in Norway in the short run. Most of the new renewable energy would be exported in the short run, however grid capacities are expected to be insufficient as RES-E increases with increasing quota. In the medium to long run on the other hand, there might be a reduction in Norwegian emissions as the new renewable energy might replace some of the consumption of fossil fuels. The short-term effect on European emissions would be marginal, as the European emissions are capped. Thus, a reduction in Norwegian emissions would only lead to increased

emissions from industries in other countries. In the long run on the other hand, the cap will be tightened since reduction in emissions in some countries would give policy makers incentives to tighten the future cap. All emission reductions are marginal, and since all EU and EEA member countries are obliged by the RES-E Directive, several small emission reductions in each country could be significant in a larger scale.

The study has illustrated that the joint Swedish/Norwegian green certificate market is a cost-efficient policy scheme when the RES-E Directive is implemented. The more participating countries, the more cost-efficient the measure would be due to different marginal cost curves for increasing RES-E in different countries. When the scheme includes several countries, the RES-E could be done where it would be cheapest and countries with expensive RES-E would have the opportunity to buy certificates from other countries instead of producing RES-E on their own. Cost-efficiency would then be gained.

R&D will not increase significantly in Norway with the regulation of the green market, despite increased RES investments. Increased activity in the Norwegian petroleum sector the upcoming years would cause a lack of engineers in Norway. R&D in the renewable energy sector would then come to halt if not imported labour could make up for some of the engineer shortage.

Predictability of investment subsidies would increase when the responsibility of subsidising RES investments is being transferred from the government to the consumers. When the consumers are subsidising green producers directly, political governance does not influence the assigning funds and thus predictability increases. Since the joint green certificate market only include Norway and Sweden, conflicts of interests and market outcomes could affect the structure or the lifetime of the market and thus decrease predictability of investment subsidies.

References

Printed material

- Alfsen, K. H. (2009): "*Debatt: Grønne sertifikater er bra på lang sikt*". Klima 5. Cicero, Oslo, 2009.
- Amundsen, E.S. and Mortsensen, J.B. (2001): "*The Danish Green Certificate System: Some simple analytical results*". Working Paper No. 18. SNF-project No. 3082, SNF-projects No. 3135. Foundation for Research in Economics and Business Administration, Bergen, 2001.
- Amundsen, E.S. and Nese, G. (2005): "*Integrated Tradable Green Certificate Markets: Functioning and Compatibility*". Working Paper No. 3/05. SNF-Project No 3231 and No 3555. Institute for Research in Economics and Business Administration, Bergen, 2005.
- Aune, F.R., Dalen H.M. and Hagem C. (2010): "*Implementing the EU renewable target through green certificate markets*". Discussion Papers No. 630. Research Department, Statistics Norway, 2010.
- Bye, T. (2003): "*On the Price and Volume Effects from Green Certificates in the Energy Market*". Discussion Papers No. 351. Research Department, Statistics Norway, 2003.
- Bye T. and Hoel M. (2009): "*Grønne sertifikater – dyr og formålsløs fornybar moro*". Samfunnsøkonomen nr. 7, 2009.
- Bye T., Olsen O.J. and Skytte K. (2002): "*Grønne sertifikater – design og funksjon*". Statistics Norway, Oslo, 2002.
- Bøeng, A. C. (2010): "*Konsekvenser for Norge av EUs fornybardirektiv*". Økonomiske analyser 4. Seksjon for energistatistikk/Gruppe for økonomisk vekst og miljø, Forskningsavdelingen. Statistics Norway, 2010.
- Böhringer C. and Rosendahl K.E. (2009): "*Satsing på fornybar kraft = satsing på kullkraft*". Samfunnsøkonomen nr. 7, 2009.
- ECON Analyse (2004): "*Konsekvenser av sertifikatmarked i Norge*". Rapport 2004-108. Oslo, 2004.
- Energimyndigheten (2010): "*Elcertifikatsystemet 2010*". Swedish Energy Agency.
- Goldstein, H. (2010): "*A Green Certificate Market in Norway and its implications for the market participants*". Term Paper, spring 2010. Energy Economics and Policy, ETH Zürich, 2010.
- Golombek, R. And Hoel, M. (2005): "*Pliktige elsertifikater*". Rapport 1/2005. Ragnar Frisch Centre for Economic Research, 2005.
- Gran, J. (2004): "*Mål: Mer grønn kraft, Middel: Sertifikater*". Cicerone 3. Cicero, Oslo, 2004.
- Gullberg, A.T. (2011): "*Norge som Europas grønne batteri*". Klima 3. Cicero, Oslo, 2011.

- Hagem C. and Rosendahl, K.E. (2011): ”*Elsertifikater og fornybar kraft: Mål eller middel?*”. Samfunnsøkonomen nr. 3, 2011.
- Haugneland, P. (2004): ”*Grønt sertifikatmarkedet kan gi mindre grønn elektrisitet*”. Cicerone 1. Cicero, Oslo, 2004.
- Haugneland, P. (2007): ”*Bruk av bioenergi kan doubles*”. Cicerone 1. Cicero, Oslo, 2007.
- Klimakur 2020 (2009): ”*Internasjonale rammebetingelser for norsk klimapolitikk*”. Ministry of the Environment, 2009.
- Klitkou, A. (2011): ”*Virkemidler for miljøvennlig energiteknologi*”. Forskningspolitikk 1, 2011.
- Morthorst, P.E. (2000): ”*The development of a green certificate market*”. Energy Policy 28: p. 1085-1094
- Norwegian Ministry of Petroleum and Energy (1998): ”*Energi- og kratbalansen mot 2020*”. NOU 1998:11. Oslo, 1998.
- Norwegian Ministry of Petroleum and Energy (2008): ”*Fakta 2008: Energi og vannressurser i Norge*”. Norwegian government, 2008.
- Norwegian Water Resources and Energy Directorate (2011): ”*Energistatus*”. Norwegian Water Resources and Energy Directorate, Oslo, 2011.
- Pindyck, R.S. and Rubinfeld, D.L. (2005): ”*Microeconomics*”. 6th edition, p. 641-671. Pearson Prentice Hall, New Jersey, USA.
- PwC (2009): ”*Economic turmoil catches cleantech After meteoric rise, VC funding of cleantech plunges*”. PriceWaterhouseCoopers, 2009.
- Rydén, B. et. al (2006): ”*Ten Perspectives on Nordic Energy*”. Nordic Energy Perspectives. Elforsk, Stockholm 2006.
- Söderholm, P. (2008): ”*The political economy of international green certificates markets*”. Energy Policy 36: p. 2051-2062.
- Regjeringens Proposition 2008/09:163: ”*En sammanhållen klimat- och energipolitik-Energi*”. Swedish government, Stockholm, 2009.
- THEMA Consulting Group in association with vivideconomics (2011): ”*Renewables and Emissions – The Effect of Norwegian Renewable Investments on Carbon Emissions*”. THEMA Report 2011-2.
- Torvestad, C. and Johannessen, C.J.B. (2010): ”*Utfordringer ved innføringen av et grønt sertifikatmarked*”. Norwegian School of Economics, Bergen, 2010.
- Øygard, E.W. and Hansson, T. (2010): ”*Hva er konsekvensene for kraftmarkedet i Norge ved innføringen av et marked for grønne sertifikater*”. Norwegian School of Economics, Bergen, 2010.

Internet sources

- Agder Energi "Renewable Energy Certificates" Retrieved October 5, 2011 from http://www.aep-renewables.com/ae/Renewables_Trading/Power_Consumer/Renewable_Energy_Certificate/article48981.ece
- Bellona "10 års kamp kronet med seier". Retrieved November 3, 2011 from http://bellona.no/jubileum25/hjertesaker/10aars_kamp
- BT.no Aadland, C. (2011): "Er nær det systemet kan tale". Retrieved 30.11.11 from <http://www.bt.no/nyheter/lokalt/--Er-nr-det-systemet-kan-tale-2618450.html>
- Øyehaug, O. and Gaasemyr, M. (2011): "Spår gloheitt oljebransje". Retrieved November 11, 2011 from <http://www.bt.no/nyheter/okonomi/Spr-gloheitt-oljebransje-2607579.html>
- Dn.no "Vil ha billigere strøm". Retrieved November 5, 2011 from <http://www.dn.no/forsiden/politikkSamfunn/article2113669.ece>
- Enova.no "Resultatrapport". Retrieved September 23, 2011 from <http://enova.no/sitepageview.aspx?sitePageID=1170>
- European Commission "Renewable Energy. Targets by 2020". Retrieved October 6, 2011 from http://ec.europa.eu/energy/renewables/targets_en.htm
- Fornybar.no "Vannkraftressursser i Norge" Retrieved August 29, 2011 from <http://fornybar.no/sitepageview.aspx?sitePageID=1855>

-
- "Elsertifikater for grønn kraft"*. Retrived August 29, 2011 from
<http://fornybar.no/sitepageview.aspx?sitePageID=1765>
- Global Wind Energy Council *"Europe"*. Retrieved October 17, 2011 from
<http://www.gwec.net/index.php?id=11>
- Ministry of the Environment *"Avtale om Klimaforliket"*. Retrieved November 15, 2011 from
http://www.regjeringen.no/Upload/MD/Vedlegg/Klima/avtale_klimameldingen.pdf
- Kraftverk.net *Glette, H. (2011): "Statsministeren: Elsertifikater vil gi lavere strømpris"*. Retrieved November 16, 2011 from
<http://kraftverk.net/visartikkel.php?id=2064>
- Nordic Energy Perspectives *"RES deployment profoundly changes the market balance of the Nordics"*. Retrieved October 8, 2011 from
<http://www.nordicenergyperspectives.org/Trade%20within%20the%20RES%20directive%202.pdf>
- "Decreased import dependence with EU's 20% goals"*. Retrieved October 8, 2011 from
http://www.nordicenergyperspectives.org/Decreased_import.pdf
- Nord Pool Spot *"Price calculations"* Retrieved September 1, 2011 from
<http://www.nordpoolspot.com/How-does-it-work/Day-ahead-market-Elspot-/Price-calculation/>
- "About the Nordic Power Exchange"* Retrieved September 1, 2011 from
<http://www.nordpoolspot.com/About-us/>
- Norwegian Energy Resources and Water Directorate *"Vindkraft"*. Retrieved August 27, 2011 from
<http://www.nve.no/no/energi1/fornybar-energi/vindkraft/>
- "Vindkraft og produksjonsstatistikk"*. Retrieved August 18, 2011 from
http://www.nve.no/pagefiles/9272/vindkraftproduksjon_2009.pdf

- "Ressurskartlegging små vannkraftverk"*. Retrieved August 23, 2011 from <http://www.nve.no/no/Energi/Fornybar-energi/Vannkraft/Ressurskartlegging/>
- Ministry of Petroleum and Energy Blakstad, E. (2011): *"Ambisiøst mål for fornybar energi"*
Retrieved November 13, 2011 from http://www.regjeringen.no/nb/dep/oed/aktuelt/taler_artikler/politisk_ledelse/taler-og-artikler-av-statssekretar-eli-b/2011/ambisiost-mal-for-fornybar-energi.html?id=651738
- "Norge og Sverige enige om et felles sertifikatmarked"*. Retrieved October 5, 2011 from <http://www.regjeringen.no/nb/dep/oed/pressesenter/pressemeldinger/2010/norge-og-sverige-enige-om-et-felles-else.html?id=627384>
- "Enige om prinsippene for et felles elsertifikatmarked"* Retrieved October 5, 2011 from <http://www.regjeringen.no/nb/dep/oed/pressesenter/pressemeldinger/2009/enige-om-prinsippene-for-felles-elsertif.html?id=575821>
- "Grunnlagsnotat – norske elsertifikatkvoter"*. Retrieved October 5, 2011 from <http://www.regjeringen.no/nb/dep/oed/aktuelt/nyheter/2010/lov-om-elsertifikater-pa-horing.html?id=627393>
- Statistics Norway *"Rekordhøyt energiforbruk"*. Retrieved August 25, 2011 from <http://www.ssb.no/energi/egn/>
- "Kraftig oppgang i klimagassutslippene"*. Retrieved August 27, 2011 from <http://www.ssb.no/klimagassn/>
- Statnett.no *"Kraftforbindelser med utlandet"*. Retrieved November 10, 2011 from <http://www.statnett.no/Documents/Kraftsystemet/Om%20kraftsystemet/Kraftnettet/Kraftforbindelser%20utland%20mai%202010.pdf>

"*Prosjekt Skagerrak*" Retrieved November 10, 2011 from
<http://www.statnett.no/no/Prosjekter/Skagerrak-4/>

"*Prosjekt Nordlink*" Retrieved November 10, 2011 from
<http://www.statnett.no/no/Prosjekter/NORDLINK11/>

"*Prosjekt England*" Retrieved November 10, 2011 from
<http://www.statnett.no/no/Prosjekter/Kabel-til-England/>

Swedish Energy Agency

"*Om Elcertifikatsystemet*". Retrieved September 17, 2011 from
<http://www.energimyndigheten.se/sv/Foretag/Elcertifikat/Om-elcertifikatsystemet/>

"*Elcertifikatsystemet 2010*". Retrieved September 17, 2011 from
http://webbshop.cm.se/System/ViewResource.aspx?p=Energimyndigheten&rl=default:/Resources/Permanent/Static/3000afb1418f413aa41dae33186491d5/ET2010_25w.pdf

Swedish National Grid
from

"*Elcertifikat*". Retrieved September 17, 2011
<http://www.svk.se/Om-oss/Var-verksamhet/Elcertifikat/>

Tekna.no

"*Vi trenger forutsigbarhet*". Retrieved November 5, 2011 from
http://www.tekna.no/portal/page/portal/tekna/aktuelt/artikkel?p_document_id=816652

TU.no

Nilsen, J. (2011): "*Europa venter ikke på Norge*". Retrieved November 5, 2011 from
<http://www.tu.no/energi/article280680.ece>

Nilsen J. and Lie, Ø. (2011): "*Vindmøllene skuffer år etter år*". Retrieved October 28, 2011 from
<http://www.tu.no/energi/article292761.ece>

Ree, M. and Helgesen, O.K. (2011): "*Oljebransjen tømmer Norge for ingeniører*". Retrieved November 17, 2011 from

<http://www.tu.no/olje-gass/article293830.ece>

Vindkraft.no

“*Vindproduksjon i Europa*”. Retrieved August 28, 2011 from

<http://www.vindkraft.no/Default.aspx?ID=149>

”*Kostnader vindkraft*”. Retrieved September 3, 2011 from

<http://www.vindkraft.no/Default.aspx?ID=180>

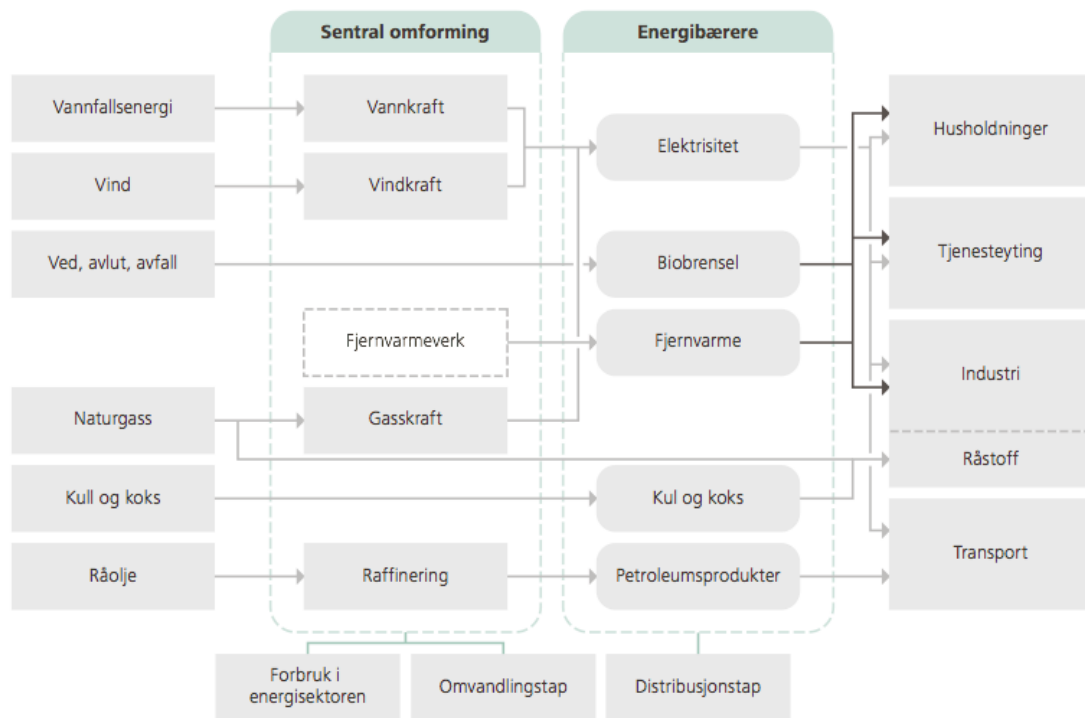
Zero.no

Lunde, E. (2010): “*Fornybarløft gir klimagevinst og arbeidsplasser*”. Retrieved November 6, 2011 from

<http://www.zero.no/fornybar-energi/fornybarloeft-gir-klimagevinst-og-arbeidsplasser>

Appendix A

A model of the Norwegian energy system



Source: Norwegian Water Resources and Energy Directorate, 2011

Appendix B

National Targets for EU member countries of shares of energy from renewable sources in 2020

National targets

National overall share and targets for the share of energy from renewable sources in gross final consumption of energy in 2020

	Renewable energy %*		
	2005	2009 (prov.)	2020 target
Austria	23,3	29.2	34
Belgium	2,2	3.8	13
Bulgaria	9,4	11.5	16
Cyprus	2,9	3.8	13
Czech Rep	6,1	8.5	13
Denmark	17	19.7	30
Estonia	18	77.7	25
Finland	28,5	29.8	38
France	10,3	12.4	23
Germany	5,8	9.7	18
Greece	6,9	7.9	18
Hungary	4,3	9.5	13
Ireland	3,1	5.1	16
Italy	5,2	7.8	17
Latvia	32,6	36.8	40
Lithuania	15	16.9	23
Luxembourg	0,9	2.8	11
Malta	0	0.7	10
Netherlands	2,4	4.2	14
Poland	7,2	9.4	15
Portugal	20,5	25.7	31
Romania	17,8	21.6	24
Slovak Rep	6,7	10	14
Slovenia	16	17.5	25
Spain	8,7	13	20
Sweden	39,8	50.2	49
UK	1,3	2.9	15
EU27	8,5	11.6	20

*As a share of gross final energy consumption Source: Eurostat (with normalised hydro) & (for 2009) EurObserv'er 2009(www.eurobserv-er.org)

Source: European Commission, 2009

Appendix C

Installed wind power capacity in Europe divided by country (2009 and 2010)

Land	Nr Installert	2009 [MW]	Sum 2009 [MW]	Installert 2010 [MW]	Sum 2010 [MW]
Tyskland	1	1917	25777	1493	27214
Spania	2	2459	19149	1516	20676
Italia	3	1114	4850	948	5797
Frankrike	4	1077	4245	1086	5660
Storbritannia	5	1077	4051	962	5204
Danmark	6	334	3465	327	3752
Portugal	7	673	3535	345	3702
Nederland	8	39	2223	15	2237
Sverige	9	512	1560	604	2163
Irland	10	233	1260	118	1428
Tyrkia	11	343	801	528	1329
Hellas	12	102	1087	123	1208
Poland	13	181	725	382	1107
Østerrike	14	0	995	16	1011
Belgia	15	149	563	350	911
Romania	16	3	14	448	462
Norge	17	2	431	10	441
Bulgaria	18	57	177	198	375
Ungarn	19	74	201	94	295
Tsjekkia	20	44	192	23	215
Finland	21	4	146	52	197
Litauen	22	37	91	63	154
Estland	23	64	142	7	149
Ukraina	24	4	94	1	91
Kroatia	25	10	28	61	89
Kypros	26	0	0	82	82
Luxembourg	27	0	35	7	42
Sveits	28	4	18	25	42
Latvia	29	2	28	2	31
Russland	30	0	9	0	9
Slovakia	31	0	3	0	3
Sum		10515	75895	9886	86076
Offshore utgjør		582	2064	883	2945

Source: Vindkraft.no, 2011