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How Do Various Risk Factors Influence the Green Certificate Market of Norway and Sweden?

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Abstract

The EU renewable energy directive sets a target of increasing the share of renewable energy used in EU to 20% by 2020. The Norwegian goal for the share of renewable energy in 2020 is 67.5%. The most important policy instrument for reaching this national target is the introduction of the common market for green certificates between Norway and Sweden. This new market mechanism is promoting new, renewable power projects until 2020, and is expected to generate 26.4 TWh from 2020.

The market mechanism is neutral regarding renewable technologies, and the two countries share the same level of ambition regarding production increases of the common market. In the green certificate market the power producers receive electricity certificates from the authorities, and these can be sold to electricity suppliers and certain electricity users. The electricity customers cover the costs of the system, as the costs of purchasing certificates are added to the electricity bill. The price of electricity certificates is determined by supply and demand.

A new energy system model covering Norway and Sweden is developed to analyze the impact of the green certificate market. The model covers five Norwegian and four Swedish regions, with exchange of electricity between adjacent regions and neighboring countries. Various scenarios are analyzed, focusing especially on various risk factors (e.g. grid expansion, delays of new power plants, transmission grid limitations, coordination issues between grid and power projects, licensing issues, etc), as well as the impact of variations in energy demand, energy prices and certificate prices. The analyses indicate the choice of power plant technology being installed depending on the scenario assumptions, as well as the timing and the geographical location of the various plants.

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1. Introduction

The EU Renewable Energy Directive [1] sets a target of increasing the share of renewable energy use in the EU to 20% by 2020 (up from 8.5% in 2005) in order to limit the greenhouse gas emissions and to promote cleaner transport. The directive is part of a package of energy and climate change legislation commonly referred to as the “20-20-20 targets”. The additional targets include a 20% reduction in EU greenhouse gas emissions and a 20% improvement in the EU's energy efficiency. The directive is implemented in Norway with a national target of 67.5% renewables in 2020, roughly calculated as the renewable energy production plus the direct use of bio energy divided by the total end use of energy. One important measure in achieving this target

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is the common Green Certificate Market (GCM) that is agreed upon by the governments of Sweden and Norway. This new market mechanism is promoting new, renewable power projects, and is expected to generate 26.4 TWh of electricity by 2020. The use of green certificates to reach renewable targets has previously been considered in e.g. [2], and an analytic study of a tradable green certificate system can be found in [3].

This paper describes how a technology-rich optimization model can be used to analyze how various risk factors influence the green certificate market of Norway and Sweden. A brief overview of the GCM is given in section 2. Section 3 describes the methodology and the TIMES-NoSe model, whereas the scenario assumptions are given in section 4. The model results are presented in section 5 and discussed in section 6.

2. The green electricity certificate system

2.1. Introduction

The GCM is neutral regarding renewable power technologies, and both countries share the same level of ambition regarding production increases of the common market. The electricity production in Norway is mainly based on hydropower, where the production is dependent on the annual precipitation which fluctuates with stochastic behavior. The actual production was 147.8 TWh in 2012 [4], whereas the annual hydropower production is 130.5 TWh based on the normalization method described in [1]. The annual potential of hydropower in Norway was in 2013 estimated to be 214.1 TWh [5], approximately 61% more than the existing production. However, 50.8 TWh is restricted due to nature conversion. Norway has also a significant potential for electricity production from both onshore and offshore wind facilities. As of early 2014, the total installed wind capacity in Norway was 811 MW [6], corresponding to an electricity production of around 1.9 TWh.

Unlike Norway, Sweden uses a combination of hydropower, nuclear power, and conventional thermal power. The hydropower stations are located mainly in the northern areas, whereas the thermal power stations prevail in The South. As for Norway, the hydropower output in Sweden varies considerably from season to season due to the fact that the hydrological balance shifts considerably. Therefore, the annual share of renewable power production varies significantly from year to year. The actual hydropower production in 2012 was 78 TWh [7], whereas the normalized production is 65.5 TWh. Additionally, 4% of the total Swedish electricity production (7.2 TWh) came from wind power in 2012, and the production from CHP plants were 15.5 TWh.

2.2. How the electricity certificate market works

The electricity certificate market system in Norway and Sweden works in such a way that the power producers are issued electricity certificates based on the actual production from approved power plants. One certificate is issued per MWh of net renewable electricity produced within the two countries. Electricity production from biofuels, geothermal energy, solar energy, hydro energy, wind energy, and wave energy can receive certificates. Plants entitled to receive certificates can only do so for a maximum of 15 years, and no longer than ultimo 2035.

The electricity producers can sell the certificates, thereby obtaining an extra income in addition to the price charged from the production itself. Electricity suppliers, in addition to some end users, have an obligation to buy certificates for a certain proportion of their electricity sales (quota obligation). The quotas, which are different for the two countries, will increase towards 2020, leading to an increased demand for electricity certificates. Quota curves have been constructed for both countries based on assumptions regarding future electricity consumption, and also so that certificates corresponding to an electricity production of 198 TWh will be cancelled (13.2 TWh x 15 years) for each country. The quota curve gives the annual quota (in %) for both countries until 2035. This quota is then used to calculate the additional costs for the electricity consumers as a function of the quota, electricity consumption, and electricity certificate price. This additional cost is then added to the electricity bill, meaning that the electricity customers cover the cost of the system.

Trading of an electricity certificate is performed in a common electricity certificate market. Here, the price is determined by supply and demand. The market participants with quota obligations must be in possession of sufficient electricity certificates as given by a combination of the quota curve and the electricity usage. Each year, the market participants with quota obligations must be in possession of sufficient electricity certificates. At the 1st of April, the electricity certificates are deleted, forcing the market participants to purchase new certificates for the next period. Consequently, a demand for electricity certificates is constantly being created.

2.3. Potential risk factors

There are many potential risk factors that can influence the production increase within the electricity certificate system. The most important ones are briefly discussed below, and some of them are analyzed further by using the TIMES-NoSe model.

In order to install a new power plant, a license from the national authorities is required. Obtaining such a license is a comprehensive process, and it is not unusual that the approval process takes several years. As an example, the average approval time is 2.7 years in Sweden. It is therefore very important to minimize the approval time in order to keep the rollout rate of new power plants at a significant level. In addition, it typically takes 1-2 years from a license is given to the construction of the power

plants begins. On top of that, the construction time for wind power plants is roughly two years, whereas the construction time for hydropower varies between 2.5-4 years (depending on the size). This risk factor is included in the TIMES-NoSe model by using a so-called growth constraint, which limits the annual electricity production increase to a certain level.

For both Norway and Sweden, the expected production increase can lead to challenges for the electricity transmission grid. Although both countries have extensive plans for expanding and strengthening the grid, the various measures may come too late according to the 2020 limit. The two northernmost price regions in Sweden have a large potential for new wind power plants. However, the transmission grid in some regions has a limited capacity for new power projects, but the grid expansion will only take place once the power companies have made positive investment decisions on a sufficient number of wind power projects. If the progress of these wind power investment decisions is slow, the time window up to 2020 may be too narrow for the grid expansion. If a significant amount of new renewable power production is installed in areas with limitation in the transmission grid capacity, a capacity deficit can occur. This can lead to more frequent price differences between the various price areas, and consequently, the investors may decide to postpone the power production investments until the transmission grid capacity is sufficient. The risk is then that when the investment decision regarding e.g. a new wind power plant is finally taken, the time window up to 2020 is too narrow for the construction to be ready in time. This risk factor is also included in the TIMES-NoSE model by using different scenarios which takes into account variations in the expansion and strengthening of the electricity transmission grid.

In order to have a well-functioning market, it is of high importance that all the market participants have sufficient information regarding market developments. This kind of information is of high importance in order to make forecasts of future certificate prices and surplus of certificates (= electricity certificates issued but not cancelled), which again is used for making investment decisions. Lack of information regarding how much capacity that is entering the market, in addition to incomplete information regarding future energy demand, can increase the uncertainty for the investors. This risk factor is analyzed further by investigating the effect of varying certificate prices.

In Norway certificates will be issued to approved plants in operation before 31st of December 2020, while in Sweden certificates will also be issued to plants coming in operation later. There is a concern, especially in Norway, that those who choose to construct new plants close to 2020 do not reach the deadline. Increased time pressure towards 2020 can have several negative effects. First and foremost, it is a risk that new power plants and grid expansions are not ready in time. Secondly, time pressure can give increased investment costs and also deteriorate the quality of the installation. There is also a possibility that projects that are economic profitable under the certificate market may be cancelled due to the risk of not reaching the deadline. Since the TIMES-NoSe model assumes perfect foresight, which is to say that all investment decisions are made in each period with full knowledge of future events, there will be a clear distinction between which facilities that receive certificates and not.

The EU Water Framework Directive [8] aims to protect and restore clean water across Europe and ensure its long-term, sustainable use. Consequently, the directive may be in conflict with potential hydro power projects in the two countries. In the TIMES-NoSe model, this can be taken care of by adjusting the future hydropower potential (see scenario variant B).

Access to sufficient funding is an absolute necessity for reaching the 26.4 TWh target for 2020. Banks and other financial institutions may be reluctant to offer financing to various projects if the market conditions are too uncertain. Consequently, there is a risk that lack of funding may interfere with the 2020 target, but this is not included in TIMES-NoSe.

Both tax levels and depreciation rates vary between Norway and Sweden. These issues will influence the production costs for the various renewable technologies in the two countries. Although this may not be seen as a risk factor for reaching the common target for 2020, it can clearly affect in which country new facilities will be installed.

3. Modelling framework: TIMES-NoSe

3.1. Model structure

The structure of the TIMES-NoSe model is illustrated in Figure 1. TIMES (The Integrated Markal Eform System) is a bottom-up, techno-economic model generator for local, national or multi-regional energy systems [9]. It comprises a technology-rich basis for estimating energy dynamics over a long-term, multi-period time horizon.

A TIMES model gives a detailed description of the entire energy system including all resources, energy production technologies, energy carriers, demand devices, and sectorial demand for energy services. The model assumes perfect competition and perfect foresight and is demand driven. Thus the projected energy demand has to be given exogenously to the model, and the TIMES model aims to supply energy services at minimum global cost by making equipment investments, as well as operating, primary energy supply and energy trade decisions. More information regarding the TIMES modelling tool can be found in [10].

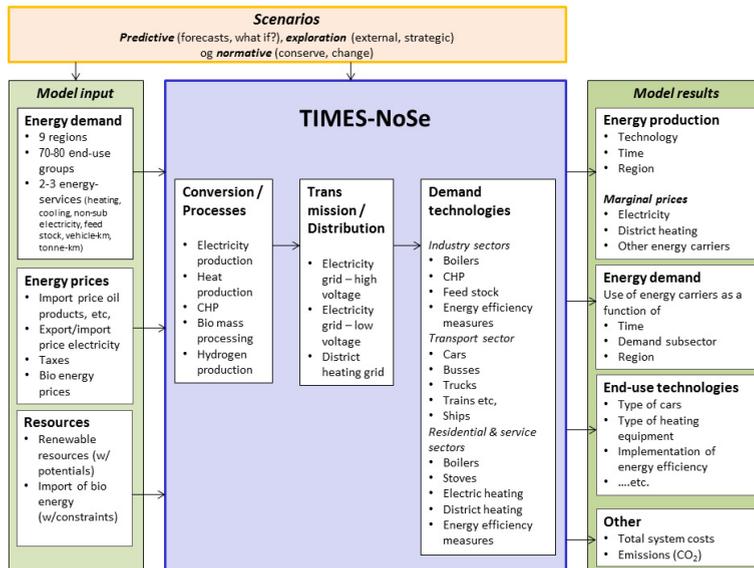


Figure 1: Principal drawing of the TIMES-NoSe model

The TIMES-NoSe model is used to analyze various risk factors related to the green electricity certificate system. The model covers both the Norwegian and the Swedish energy system. This new model is developed with a high-time resolution and a model horizon from 2010 to 2050. The Norwegian part of the model is a modified version of TIMES-Norway [11-13], whereas the Swedish part is a new model development that is hard-linked with TIMES-Norway. This means that the four new Swedish model regions are completely integrated with the Norwegian regions.

The demand for various energy services, the technical-economic characterization of energy technologies and resource costs (e.g. extraction or import costs) and availability are given exogenously to the model. On the energy supply side, several conversion processes are represented in detail, as well as transmission and distribution. The TIMES-NoSe model covers nine model regions (5 Norwegian and 4 Swedish) with exchange of electricity between adjacent regions and neighboring countries. The regional distribution in the model is based on the different market areas (pricing areas) for electricity given in the Nordic spot market [14]. This means different electricity prices in different areas, depending on supply and demand in each area.

3.2. Electricity production processes

In TIMES-NoSe electricity can be produced by a variety of different processes. For the Norwegian regions, updated technology costs and potentials have been included (see [15]) for both hydropower and wind power technologies, compared to the original values in TIMES-Norway [11, 12]. For the Swedish regions, the actual electricity production capacity for 2010 is included in the model. This is summarized in Table 1.

Table 1: Swedish electricity capacity (2010)

Capacity 2010		SE1	SE2	SE3	SE4	Total
Hydropower	MW	5 456	11 094	2 930	269	19 749
Wind power	MW	197	361	848	626	2 032
Nuclear	MW			9 277		9 277
CHP-Industry	MW	124	320	610	339	1 393
CHP-District heating	MW	182	295	2 550	1 008	4 035
Condensing power (diesel)	MW			771	1 253	2 024
Reserve power (gas)	MW			1 068	620	1 688
Sum capacity	MW	5 959	12 070	18 054	4 115	40 198

The Swedish limit on the new wind power potential is based on the Nordic Energy Technology Perspectives (N-ETP) [16], where the upper limit is 3.6 GW for offshore wind and 30 GW for onshore wind. The new power technologies are divided into four different cost classes, with different investment costs and capacity factors, for both onshore and offshore technologies. The wind power profile, for both existing and new plants, is based on Swedish wind power production statistics from 2007 to 2012.

All current nuclear power capacity is located in SE3. Current plans for upgrading the existing capacity towards 2020 are included, giving a 2020 capacity of 10.1 GW (or 72.6 TWh). However, no new investment opportunities are possible in TIMES-NoSe [17].

The potential for new hydropower plants in Sweden is based on [16], and is set to 5 TWh. According to the Swedish Energy Agency, an assumed potential increase of 0-5 TWh/year is possible before 2020. The hydropower potential of 5 TWh is divided into reservoir and run-of-river hydro with a capacity split of 64/36. A regional distribution of the new potential is based on information given in Table 1.

4. Scenario assumptions

A combination of 24 scenarios was developed in order to investigate the effect of various risk factors. An overview of the various scenarios is given in Table 2. A summary of the reference energy prices and taxes included in the model can be found in [12, 13]. In addition, the scenario variants include active national policy instruments of today.

Table 2: Scenario overview

Scenario	Description	Certificate prices (in 2005-kNOK/MWh)		
		2014	2020	2035
Each of these scenarios are combined with the eight different prices				
A: Certificate prices	The purpose is to investigate the impact of future certificate prices. The certificate prices are among others related to the surplus of certificates and energy demand forecasts. The scenarios involve variants with both constant and varying certificate prices (given exogenously) towards 2035.	1.	120	120
		2.	140	140
		3.	165	165
B: Water directive	The purpose is to investigate effects of the EU Water Framework Directive. As an assumption, the potential for new hydropower plants in Sweden is 1.7 TWh (only run-of-river) in this scenario, and a 2020 limitation of 7.3 TWh for Norway.	4.	182	182
		5.	120	165
		6.	120	165
C: Grid limitations in Norway	The purpose is to investigate effects of limitations in the electricity transmission grid. Consequently, limitations in the current transmission grid regarding the possibility for new power plant projects are used as a constraint.	7.	165	120
		8.	182	140

5. Results

Figure 2 summarizes the model results from the 24 scenarios. As shown in the figure to the left, the power production increases in both countries as a consequence of the green certificate market. For Norway, the average production increase from 2010 to 2035 is around 25.6 TWh, whereas the Swedish production increase is around 28.1 TWh. However, the entire production increase in Sweden is not fully renewable, since it is assumed an increased nuclear capacity [17].

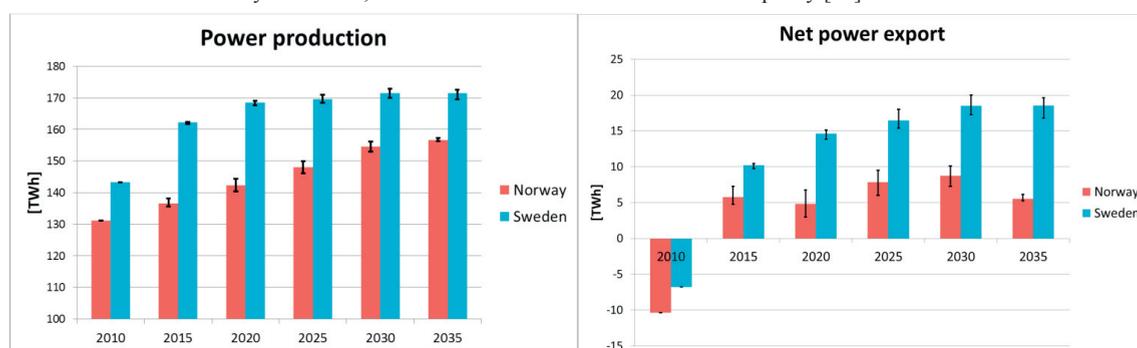


Figure 2: Average power production for the various scenarios with max/min values (left) and average net power export for the various scenarios with max/min values (right)

In 2020, the green certificate market contributes to significant investments in renewable power technologies. For Norway, the model results show an increased production from reservoir hydropower (varying from 2.4 to 4.6 TWh), run-of-river hydropower (3.3 to 4.9 TWh), and onshore wind power (2.1 to 4.5 TWh). The variety in technologies is larger in Sweden, including biofuelled CHP plants (5.1 to 5.4 TWh), reservoir hydropower (0 to 1.1 TWh), run-of-river hydropower (0.8 to 0.9 TWh), onshore wind power (5.8 TWh), and offshore wind power (0.2 TWh).

As shown to the right in Figure 2, the model results show that both countries will be net exporters of electricity towards 2035. Although the production increase for both countries is roughly of the same size, the increase in net power export is clearly higher for Sweden. One reason for this difference is that the electricity demand in Sweden (given exogenously to the model, and based

on [17]), reaches its maximum value in 2020, before declining slightly. The heat demand projections for district heating also declines slightly from its 2010 value. For Norway the situation is totally different, with an increased energy demand for nearly all end-use sectors (constant demand for the industry sector), leading to a smaller net export than for Sweden.

Figure 3 shows the average renewable power production in 2020 due to the GCM contribution for the various scenario variants. It can be seen that constant certificate values (A1-A4) give a slightly higher average value for 2020 than the certificate profile scenario variants (A5-A8), whereas the variation in the results was smaller for the latter variants. The water directive variants (B1-B8) gave a reduction in total power production for 2020 compared to A1-A8, and especially for Norway. No significant difference in production between the constant price variants (B1-B4) and the price profile variants (B5-B8) was observed. The grid limitation variants (C1-C8) also gave a reduction in total power production for 2020 compared to A1-A8, but not as severe as the water directive variants. Only a slight variation was observed between variants C1-C4 (constant) and C5-C8.

Of all the scenarios, only variant A1 gave a renewable power production of 26.4 TWh (or above) for 2020. This was also the only variant where the Norwegian contribution was higher than 13.2 TWh. For Sweden, 64% of all the scenario variants had a renewable power production of 13.2 TWh (or higher) for 2020.

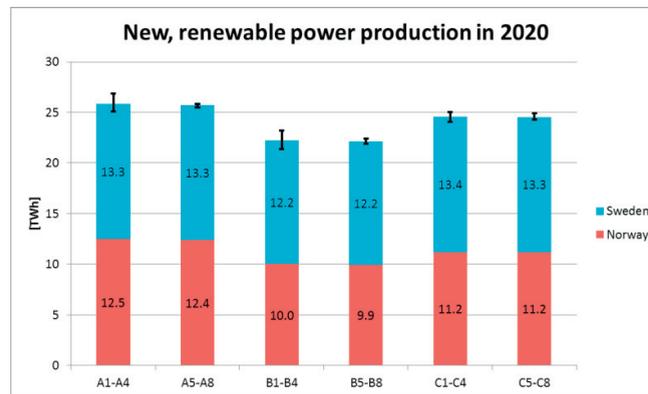


Figure 3: New, renewable power production in 2020 (average values and max/min values)

6. Discussion and conclusions

The common market for green certificates between Norway and Sweden is promoting new, renewable power projects, and is expected to generate 26.4 TWh of electricity from 2020. Analyses with TIMES-NoSe show that a combination of a sufficiently high certificate price and no additional risk factors, will give a production increase of at least 26.4 TWh from 2020. The analyses also show that unless the certificate price is sufficiently high, the GCM favors a production increase in Sweden instead of Norway.

By including different risk factors in the various scenario variants, their respective contribution on the 2020 target has been studied. As shown in scenario variants B1-B8, the EU Water Framework Directive has a significant impact on the new power production in 2020. Based on the scenario variants in this paper, the average production increase drops between 1.7 to 2.5 TWh for Norway, and approximately 1 TWh for Sweden. Scenario variants C1-C8 (grid limitations in Norway) show a moderate decrease in power production compared to scenario variants A1-A8. However, if both countries experience grid limitations due to delays regarding expanding and strengthening of the electricity transmission grid, a higher decrease in power production can be expected.

In the TIMES-NoSe model, the net power export is sensitive to the electricity prices of neighboring countries. In this paper, conservative export prices were used (constant prices from 2014). Higher export prices would most likely give an even higher net export than indicated in Figure 2, and possibly also increased power production. This part of the analyses would be improved with a model including more countries, which is currently under development.

Long-term energy demand projections are very uncertain, and the future energy demand was constant for all scenario variants in this paper. By including different demand scenarios, the production increase related to the GCM could clearly be affected in one way or another.

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