A Green Certificate Market in Norway

and its implications for the market participants

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Term Paper, spring 2010

Energy Economics and Policy

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Summary

After years of negotiations, Norway has finally decided to enter the Swedish green certificate market from 2012. In this way, producers of electricity from renewable resources in Norway will meet a whole new support-scheme, possibly motivating further investment and helping Norway to reach its goal of 30 TWh of increased production and energy efficiency by 2016 relative to 2001. A change, however, rarely comes easily and there are many challenges, both in the political and technical/regulatory sphere. The scope of this paper is to explore some of these challenges and provide an assessment of a green certificate market.

Following this scope, the paper tries to answer how a green certificate market works, how the certificate price is determined and what the implications are for the producers and the consumers. It also looks at how such a market applies to the Norwegian energy system and what additional challenges or advantages a common Swedish-Norwegian market might bring. Two main research questions are:

- To what extent will the end consumer have to pay for the development of “green” electricity in Norway?
- What are the arguments for financing this development through green certificates and for entering a common market with Sweden?

The answer to the first question turns out not to be so straight-forward. Even if the obligation to purchase the green certificates lies on the consumers, some models show that if the quota is set lower than about 25 %, the result might actually be lower prices and increased consumption for the end consumer.

With a sufficiently high quota and well-defined regulations, a green market might, however, be a cost-efficient way of subsidizing the most competitive renewable technologies, otherwise not able to enter the market. Merging this market with Sweden might further increase the economic efficiency, but potentially carries other political challenges. Some of these will be discussed in the following pages.

Introduction

Energy is a hot topic. A topic which, with the manifestation and the increasing awareness of the consequences of global warming, is growing ever hotter. Terms like energy security, “green” energy, CO_2-quotas and greenhouse gasses have already made their way into our common vocabularies. It is no news anymore: as a consequence of modern society’s massive consumption and deployment of fossil fuels, the globe is getting hotter. Most scientists and policy-makers around the world have accepted this truth and are stressing the need for an immediate change.

Despite the massive attention given to this topic, finding a global solution to a global problem is all but an easy task. Many would claim that the weak outcomes of the UN Copenhagen Climate Change Conference in 2009 is just another proof of it. Still, much has changed over the last few years in the minds of people and their perception of a sustainable future. The hope is that new technologies and renewable energy resources will solve at least part of the problem. Between many market participants the race for tomorrow’s solutions has already started.

The Norwegian government is no exception. In its proposition St.meld. nr. 11 (2006-2007) it outlines the vision of Norway as an environmentally friendly energy-nation. Norway shall be leading in the development of environmentally friendly production and use of energy. The goal is 30 TWh in increased production by renewable energy sources and energy efficiency by 2016 relative to 2001 (Energidepartementet, 2006-2007). Just as it doesn’t lack good intentions, the potential is also striking. Norway has, with its long and windy coast and its many natural waterfalls, been given the best possible starting point from nature. But in the end it all comes down to the bottom line, and the question is what means are needed to reach the goal.

Background

The Norwegian energy system

The Norwegian energy system differs notably from the respective energy systems in most other European countries in some important aspects. First of all Norway has by far the biggest consumption of electricity per capita in the world. About 50 percent of the total energy consumption in Norway (228 TWh in 2008) is in the form of electricity. This is partly due to the fact that electricity to a great extent also is used for household heating in Norway, whereas other countries rely on oil-based or district heating systems. Secondly, hydro power has been extensively expanded since the second world war, lying the fundamentals for Norwegian industrial development. More than 98% of electricity generation in Norway is from hydro power (Statistics Norway). According to the Norwegian Ministry of Petroleum and Energy, installed capacity today is almost 27 000 MW, making out almost two thirds of the total useful hydro power potential in the country. Thus, abundant access to relatively cheap hydro power has allowed Norway to heavily rely on this renewable energy resource.

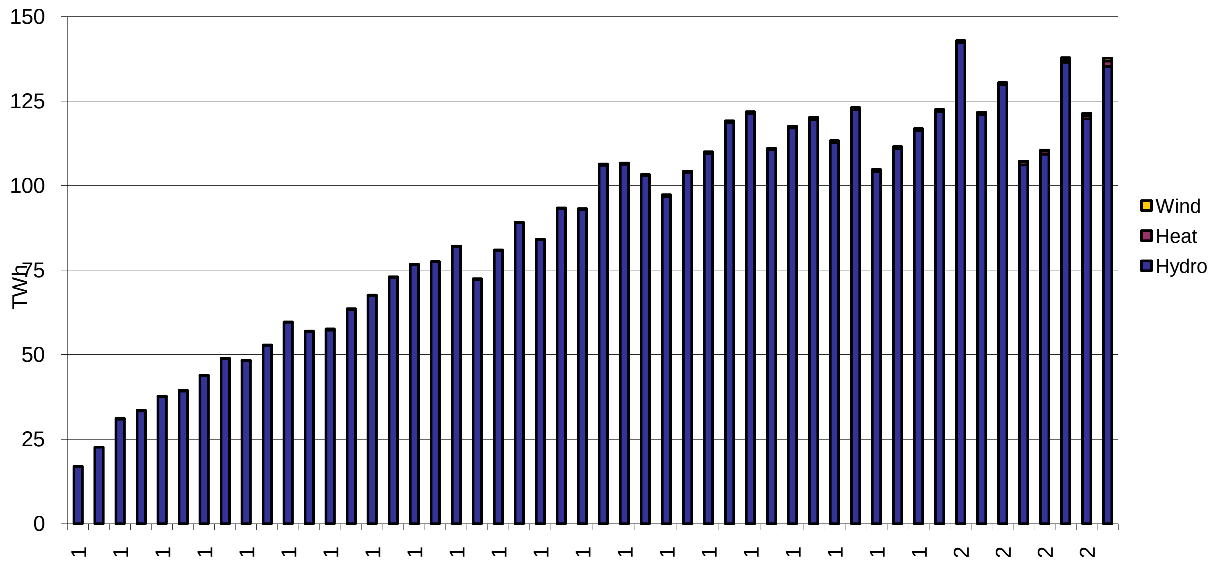

Figure 1: Yearly electricity production in Norway (TWh) from 1960 to 2006. Source: Norwegian Water Resources and Energy Directorate

The electricity market in Norway has been liberalized since 1991, making the country one of the pioneers in the later European-wide liberalization. A common electricity market was established with Sweden in 1996, and Nord Pool was later created as the world's first multinational exchange for trading electric power. Today about 60 percent of the total Nordic electricity consumption is traded on Nord Pool's spot market.

The RES Directive and its application in Norway

In April 2009 the Directive on Electricity Production from Renewable Energy Sources, popularly known as the RES Directive, was ratified by the European Union member states. Its aim is to increase the total energy originating from renewable resources in the European Union to reach 20 percent by 2020. Total energy meaning electricity, heating/cooling and transportation, this implies an extension of a previous directive from 2001 which only looked at electricity. Renewables made out only 8.5 percent of EU final energy in 2005, and thus in average 11.5 percent would need to be added by each member state to reach the overall goal (Toke 2008). However, differentiated targets were created to count for the different levels of economic capacity and available renewable resources in the different member states. See Appendix I for a full list of country targets.

Through the RES Directive the EU member states have thus emphasized the importance of renewable energy sources in combating climate change. The Directive is part of a greater focus on energy and environment within the Union, also dealing with emission trading and carbon capture and storage (CCS). In 2009, the Norwegian Government finally confirmed the RES Directive's relevance to the EEA-agreement between Norway and the EU. As a result, the Norwegian target for new renewable energy production will be calculated correspondingly to the individual targets of the European Union member states. According to Norwegian calculations this implies that Norway will have to increase its share of renewable energy from 60 to about 70-74 percent (Teknisk Ukeblad, 29.01.2009).

Wind Energy in Norway

Where should this increased production come from? In Norway, wind energy is assumed to represent the main capacity expansion when reaching for the national goal of 30 TWh increased renewable production by 2016, as well as complying with the RES Directive. With a long and windy coastline the potential for wind power in Norway is striking, theoretically thousands of TWh per year (www.fornybar.no). Already in 1998 the Norwegian Government ratified a directive on energy policy, launching an ambitious goal of reaching 3 TWh yearly electricity production from wind energy by 2010. Though despite the ambitions, Norway still has a relative modest electricity production from wind power. In 2008, only about 0.7% of the electricity in Norway is produced in wind power plants (the Norwegian Water Resource and Energy Department, 2008), making up little more than half of the 3 TWh goal. This electricity is generated in 18 wind power plants with a total installed capacity of 430 MW. As a comparison, Sweden had 1560, the UK had 4051 and Germany had 25,777 MW installed wind power by the end of 2009 (Krohn, 2010). It is obvious that great investments are needed if the goal is going to be realized.

Wind energy is by now a mature technology, but it is nevertheless dependent on financial support to enter a competitive market. This is due to the large investment-costs associated with building a wind turbine, as obviously there are no fuel costs when generating electricity from wind. Actually, as much as 75 % of the total cost of energy for a wind turbine is related to upfront costs such as the cost of the turbine, foundation, electrical equipment, grid-connection and so on (Krohn, 2009). To motivate new investments, the Norwegian Parliament has set up an Energy Fund and indicated grants within a framework of up to NOK 5 billion (app. 650 million Euro) over a ten-year period. Further funding comes from a levy on the electricity distribution tariffs (www.enova.no).

In this way, all new wind turbines in Norway can apply for investment support, which is managed by the state-owned company Enova SF. In 2003 there was a ceiling to this support of 10 % of documented investment costs, which drove many wind power investors to sell green certificates to the Netherlands for additional capital. This option was removed and the ceiling raised to 25 % in 2004, followed by a complete abolition in 2008 (www.vindkraft.no). According to the Norwegian wind power association Norwea, the investment support should make out 40 % of the costs, or about 5 million NOK (more than 600 000 €) per MW wind power installed. It is obvious that publicly financed investment support of this magnitude represents a great burden to the government and is thus dependent on strong political will.

Green certificates

The idea

An alternative to publicly financed feed-in tariffs or investment support to new, renewable energy power plants, could be the implementation of a market for tradable green certificates (TGC). Due to concerns related to environmental effectiveness and economical efficiency, as well as compatibility with a liberalized, common electricity market in Europe, several EU member countries have moved towards a green certificate support scheme in the resent years (Ringel, 2006). See Appendix II for tables with examples of different models in some European countries.

In short, with green certificates it is the end consumers of electricity that finance the renewable energy technologies, through purchase of certificates on the separate certificate market. The producers of certified “green” electricity will have the right to sell one certificate in the certificate market per unit of electricity, e.g. per kWh, produced. The certificates are thus pure financial products which are used to reach a desired production from, and investment in, renewable resources.

The government should decide how much of the final consumed electricity has to be generated from renewable energy resources. This quota could correspond to national goals for renewable energy production, and could be increased for instance every year in the relevant period. The end consumers are then obliged to cover the corresponding percentage of their electricity consumption by renewable energy resources. This is ensured through the purchase of green certificates, which in turn should finance the otherwise non-competitive renewable electricity producers. The purchase of green certificates would typically be managed by the electricity suppliers, so all the end consumer actually sees is an extra expense on the electricity bill.

In this way a demand for green certificates is created through the end consumers’ obligation to satisfy the given “green” percentage in their electricity consumption. Thus, the demand curve for green certificates will follow the total demand curve for electricity, given the quota for renewable generation set by the government.

A well-functioning green certificate market can carry many positive effects. Firstly, a great expense is removed from the public budget and placed on the end consumer. Obviously, the government might have other means of covering these expenses, for instance through various taxes on the consumer. Still, placing the responsibility of financing renewable energy resources on the end consumer means setting a direct link between electricity consumption and combating climate change. This might be found reasonable by many end consumers in the light of the growing public awareness of the linkage between energy and climate change.

Secondly, an important aspect of the tradable green certificates is the possibility of expanding the markets to include international trade. In the same way as with tradable emission permits, as in the EU Emission Trading System, this possibility allows the cheapest investments to be made first, and thus increasing the economical efficiency of the system. A country with available “green” energy, or the potential of expanding the capacity relatively cheaply, could then sell certificates to another country with more expensive renewable energy. The purchasing country could in this way fill up part of its quota, whereas the selling country could finance even more of its production and investment in renewable energies. The overall result would be the same amount of (new) renewable energy to a lower total cost.

Finally, the green certificate market would give a price-signal as to the actual cost of (new) renewable energy. As the production from renewable energy resources might be quite variable depending on the weather conditions, the income for a “green” producer can be correspondingly volatile with the changing electricity- and certificate prices. For instance, in an energy system where wind power constitutes the major part of the certified “green” production, a particularly windy year will push down the prices on both markets as the supply of both electricity and certificates from wind is increasing. However, the possibility for the producer to save the certificates in such a situation for later sale at a higher price, could offset this effect and allows the producer to increase the overall profits.

The certificate price

By selling green certificates, the producer’s price for the “green” producers is thus the sum of the electricity price and the certificate price. The certificate price will be determined by the intersection of the aggregate cost curve for all certified “green” producers and the demand for certificates. Morthorst (2000) provides a discussion of how the equilibrium price in the green certificate market is determined, as follows:

Assuming the demand of (“green”) electricity is completely inelastic, i.e. a change in price will not change the amount of (“green”) energy demanded, the demand on the green certificate market is constant and given by the vertical line in figure 2 below. This assumption is reasonable under normal conditions in a short-term perspective, e.g. within a year. The government could introduce a maximum certificate price to limit the maximum burden imposed on the end consumers. This will then constitute the continuation of the demand curve, as illustrated by the upper horizontal line in figure 2. If the price rises above this level consumers would rather choose to pay the penalty payment than buying more certificates.

Correspondingly, one could argue that also a minimum certificate price should be set, as to ensure the “green” producers a minimum revenue from the green certificate market even in times with very high production (and thereby high supply of certificates, potentially pushing the price down to a level under the minimum price). If no speculation takes place, i.e. the producer is not allowed to save the certificates to a later time with higher prices, this will constitute the lower bound of the supply curve. The first producers to enter the green certificate market will be the already existing “green” producers. Their short run marginal costs will consist of operation and maintenance costs, which, at least for new wind turbines, are relatively low. Again if no speculation takes place, these producers will enter the market as soon as the sum of the certificate price and the electricity price at least equals their short run marginal costs. Thus, the short run marginal cost of certificates will follow the aggregated short run marginal cost curve for these producers, minus the electricity price. This curve, for a given electricity price, is indicated by SRMCC on figure 2.

However, to motivate investment in new renewable power plants, the “green” quota should be set at a level above the available electricity from already existing power plants. For these plants the long run marginal costs, including investment costs and expected operation and maintenance costs, have to be taken into consideration. Following the same argument as above, the long run marginal costs of certificates will then equal the aggregated long run marginal cost curves for these power plants minus the electricity price. Now obviously future changes in the electricity price, as well as insecurities regarding expected production etc, add notably to the investment risk of these new power plants. Determination of the correct minimum and maximum price, as well as a correct prediction of the supply curve, is of crucial importance if the certificate market is going to give the wanted effect. The resulting certificate price is indicated as P_{GC} in the figure. As stated earlier this is given by the intersection of the supply- and demand curves, the former given by the short and long term marginal cost curves of the “green” producers.

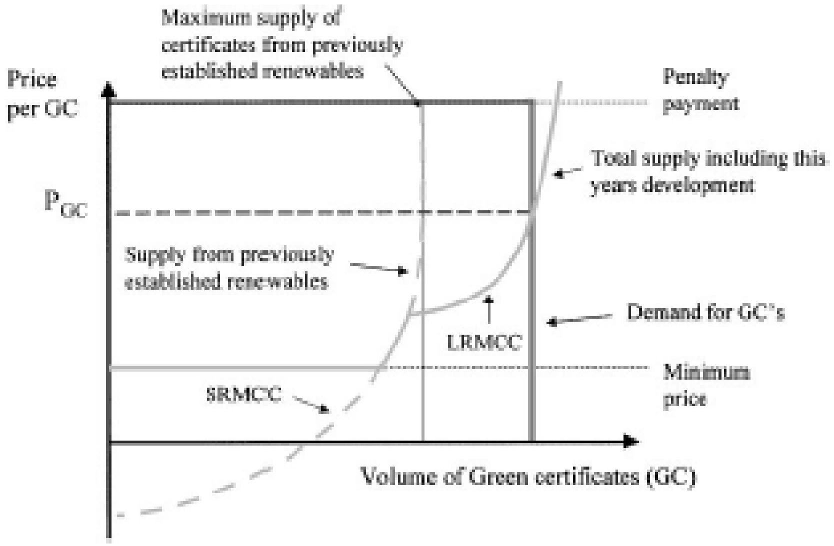

Figure 2: Demand and supply in a green certificate market. Morthorst (2000)

Implications for the market participants

What is the implications for the different market participants from introducing the green certificates? As already mentioned, the consumer price is the sum of the electricity price and the certificate price, multiplied by the relevant quota α. The demand x^D is then a function of the consumer price:

$$p_x = p + \alpha p_c$$

$$x^D = f(p + \alpha p_c)$$

At first sight, this would imply a higher price and a lower demand for the end consumer. This is, however, not necessarily the case. As argued by Bye and Hoel (2009), referring to Amundsen and Mortensen (2001), Bye (2003) and Golombek and Hoel (2005), who pays in the end depends on the price elasticities of both consumers and producers. With increasing marginal costs in the supply and a falling demand curve, the windfall profits can actually lead to cheaper electricity for the end consumer. We will come back to this point shortly.

The producer price for the “green” producers is the sum of the electricity price and the certificate price:

$$p_g = p + p_c$$

As a part of the electricity demand, corresponding to the relevant quota, is removed from the conventional market, the most expensive conventional producers will be squeezed out of the market. However, as this demand is going to be fully replaced by “green” producers, the *initial* effect could be an increased supply and thus lower electricity prices. In equilibrium, the demand should equal the supply in both markets. If the “green” quota is α then the remaining amount (1-α) will be demanded from conventional energy supply. The supply-functions *g(p)* and *h(p+*p_C*)*, for conventional and “green” electricity obviously depend on the respective price-elasticities of supply. The equilibrium will then be given by the following equations:

$$(1-\alpha)f(p+\alpha p_c) = g(p)$$

$$\alpha f(p+\alpha p_c) = h(p+p_c)$$

An interesting question is now how the “green” quota α will influence the different market prices, and thereby the market equilibrium. Bye (2002) models the relative changes in the electricity price, the certificate price and the consumer price (as given by p_x above) with a change in the “green” quota α, and comes to the result that the electricity price will sink and the certificate price will increase, whereas it is unclear wether the consumer price will increase or decrease as the imposed share α increases. The latter result is especially interesting and is depending upon the share α and the elasticities of supply for both the conventional and “green” producers. Golomek and Hoel (2005) also reach similar results. We will here only refer to Bye (2002) and reproduce two figures illustrating these results, see below.

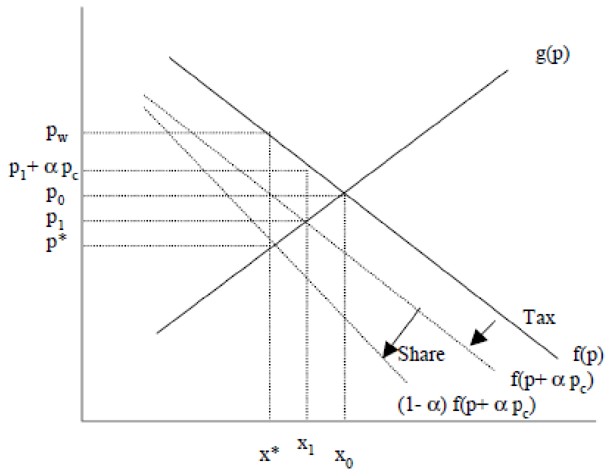

Figure 3: Introduction of green certificates and effects in the conventional electricity market. Source: Bye (2002)

In figure 3 the effects on the conventional electricity market when a green quota is introduced is illustrated. Note that the demand here has a relative high price-elasticity, which is quite a different approach from the one taken by Morthorst (2000). This second illustration should therefore be seen in a long term perspective, where the electricity demand might be more elastic to changes in prices. The underlying assumptions and elasticity estimations can change the whole picture, and caution should therefore be made when drawing conclusions from such models.

The addition in the consumer price can be seen as a tax on consumption, and will shift the demand curve down to the left such that, in the conventional market, less electricity is demanded at a lower price in the new equilibrium, see figure 3. However, as only the amount *(1-α)* will be demanded at the market of conventional electricity, the resulting price for the conventional producers is even lower than with a normal tax. Thus, a smaller amount of electricity, corresponding to x* at the price p*, is supplied by the conventional producers. The most expensive producers,. i.e. those with the highest marginal costs, will be squeezed out of the market.

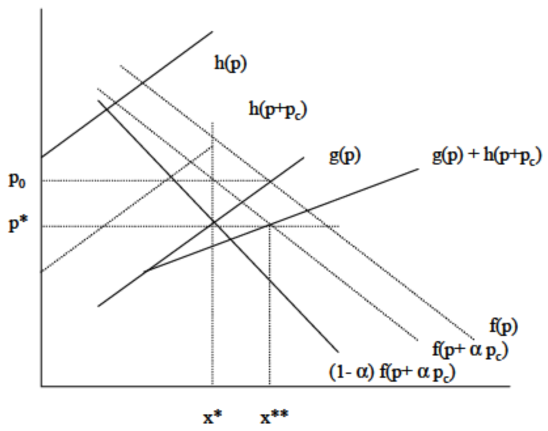

Figure 4: Market equilibrium after the introduction of green certificates. Source: Bye (2002)

Figure 4 illustrates the demand curves of both the "green" and conventional energy and the demand before and after the introduction of the green certificate quota α. Again, the relatively big elasticity of demand in the model should be noted. Initially, the green technologies are too expencive to enter the market, illustrated by the upper left curve marked h(p). With the additional income from the certificate price, however, this electricity can be offered at a lower electricity-price. The curve is shifted downwards and added to the supply of conventional electricity, here marked as g(p). The total supply curve is then the resulting $g(p)+h(p+p_C)$. With the introduction of the green certificate the demand curve of electricity is shifted downward as described in figure 3. Now the resulting electricity price is p* with the total electricity demand of x**, and demand for conventional electricity of x*.

As mentioned earlier it can be shown that the effect of an increasing "green" quota α on the the consumer price of electricity is ambigous. Bye, Olsen and Skytte (2002) claim that both the producer-and the consumer price will be sinking, implying an increased demand for electricity, as long as the quota is less than about 25 %. They argue that if the consumer is going to accept the green certificates then the conventional producers have to be sqeezed to the point where the resulting, total price for the consumer is actually sinking. Thus, the producer would take the whole loss and the consumer would benefit from both lower price and bigger consumption.

No matter what happens to the consumer price, Bye, Olsen and Skytte (2002) argue that the existing producers in the conventional market *indirectly* will subsidize the new installed capacity. As the electricity price is pushed downwards after the introduction of the green certificates, the revenue of the remaining producers in the conventional market will also decrease. Thus the producer surplus for these producers decrease. The Norwegian Water Resource and Energy Directorate support these somewhat contra-intuituive results in its report on the introduction of green certificates in Norway. The claim is however that electricity-trade with countries outside the certificate market, implying a more stable electricity-price domestically, will lead to a higher consumer price in the country with the "green" quota. In the same time, they conclude that a common certificate market between more countries is economically better for the society as a whole.

A common green certificate market

One of the main advantages of a common market for green certificates, relative to e.g. two isolated national markets, is that the wanted increase in "green" electricity production can be reached in a more cost-efficient way. This is explained for instance in Söderholm (2008) by use of the figure reproduced on the next page:

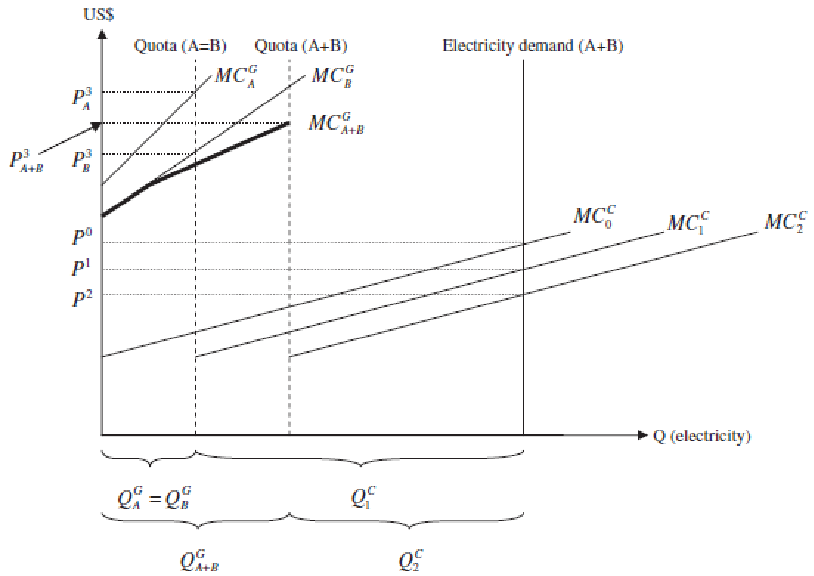

Figure 5: An integrated green certificate market and the interaction with the conventional electricity market. Source: Söderholm, 2008

Here, the demand for electricity in countries A and B is again assumed to be perfectly inelastic, and is represented by the vertical line to the right in figure 5. The two countries, as is the case between Norway and Sweden, have a common market for electricity. The initial equilibrium, where no "green" electricity enters the market, is given by the intersection between the demand curve and the marginal cost curve for conventional energy, here denoted as MC_0^C. If only one country introduces a green certificate market, then the supply-curve of the *conventional* electricity would be shifted to the right corresponding to the green quota demanded, leading to a reduced electricity price in both countries (now $p^1<p^0$). As noted earlier, the certificate price would be the difference between the marginal cost curve for the "green" producers in the respective country, minus the new price on electricity. This is the additional subsidy required to make the "green" electricity competitive, and would amount to p_A^3-p^1 for country A and p_B^3-p^1 for country B.

If both countries would implement separate green certificate markets with the same quota $Q_A^G=Q_B^G$, this would again shift the supply curve for the conventional electricity and push the price down to p^2. Now, the certificate price in both markets would increase as the marginal cost curves for the "green" electricity remain the same, but the market price of electricity is lower. In other words, the subsidy required to make the "green" producers competitive is bigger in both countries.

As mentioned above, one expects an efficiency gain by merging the two markets. This is because of the difference in the marginal cost curves of "green" production in the two countries, such that the cheapest production will be subsidized first. In figure 5, the aggregate marginal cost curve is labeled

MG^{G}_{A+B}. As shown in the figure, the resulting certificate price lies in between the certificate prices in the two separate markets. Thus, the country with the cheapest "green" electricity will be a net exporter of green certificates whereas the country with the more expensive "green" electricity will be a net importer.

The Swedish-Norwegian case

Since 2003, there has been a market for green certificates in Sweden. The goal was then to increase the generation of electricity from renewable resources with 25 TWh by 2020. All certified producers receive a certificate per MWh of electricity produced. Already existing producers will receive certificates until 2012, while producers established after 2003 will receive certificates in a maximum of 15 years, and no later than the end of 2030. The initial quota was set at 7.4 % increasing to 17.9 % in 2012 and then decreasing to 4.2 % in 2030 after a small fluctuation (Swedish Energy Agency).

In December 2004 the Norwegian government issued a law proposal for a similar green certificate system. The aim at the time was to adjust the design of the Norwegian system to make it compatible with the Swedish one. In this way it was anticipated that a common bilateral market for green certificates could have been established already in 2006 or 2007 (Söderholm, 2008). The negotiations, however, did not go as planned, and were resumed only in late 2007. September 7 2009 an agreement was finally signed, with the intentions to enter a common market from January 1 2012. The difficult negotiations and many delays in the plans are partly due to different ambition levels and disagreements regarding the quota and the different definitions in the agreement. This illustrates the importance of designing a compatible system in the two countries, and the many challenges such a system might pose.

For instance, it can be percieved as unfair if the definitions of which "green" producers are qualified for selling certificates is different in the two countries. The aim is that only producers who otherwise would not be competitive should receive the additional support, and thus for instance large hydro power plants are exempted. Also, if price floors and ceilings are to be implemented (as is the case in the Swedish system) these should be set at an equal level as to avoid incompatibilities in the system. For instance, in a situation with shortage of supply of green certificates the price could rise drastically. Then, the lower of the two price ceilings would be the binding constraint. In other words, all consumers would prefer to buy the cheaper certificates in the country with the lowest maximum price, making the price ceiling in the second country irrelevant. Finally, different "green" quotas in the two countries will influence the electricity prices in both countries, as this only depends on the total quota in the two countries (see figure 5). Difficulties in reaching an agreement regarding the realtive quotas largely explains why the first negotiations between Norway and Sweden broke down (Söderholm, 2008).

The argument of economical efficiency outlined in the previous chapter is very close to that applied to tradable emission permits in the EU (the EU ETS). The idea is here, again, that the emission reduction can be made most efficiently in the country with the lowest abatement costs, and thus the relative emission reductions are allowed to be traded. There are however some important differences in these two policy issues, many of which are thoroughly discussed in Söderholm (2008). Firstly, it might be harder to justify an additional tax on electricity consumption if this is only used to subsidize investments in a different country. This is related to the primarily local interests of renewable energy resources, for instance related to new jobs or nature interventions, whereas the benefits from a bigger overall "green" electricity production from renewable energy resources might be less obvious for the end consumer. Secondly, an integration of the markets might lead to homogeneity in the "green" production as the system is technology neutral and the cheapest technologies will be produced first. A more differentiated and independent energy system, ensuring the domestic security of supply, is one of the main arguments applied by many European governments to increasing the production by renewable energy resources (Ringel, 2005). In this context an integrated, potentially European-wide, certificate system can hardly be justified. On the other hand, a larger system will contribute to a greater stability and lower price-volatility, as the "green" production is spread over a larger area and can benefit from different weather conditions.

Which "green" producers would then be supported by a common Swedish-Norwegian green certificate market? In 2009 the average electricity price in Norway was 36,3 Norwegian øre/kWh (4,4 €c/kWh) while the price in the Swedish certificate market was 24,2 Norwegian øre/kWh (2,9 €c/kWh). With these prices renewable electricity production with long term marginal costs of up to 60,5 øre/kWh (7,3 €c/kWh) could be competitive (www.fornybar.no). The results of Unger and Ahlgren (2004) show that in the short- and medium term, biomass energy will be the most important green electricity source in the Swedish-Norwegian market. This energy source is generally cheaper in Sweden than in Norway, and thus mostly Swedish power plants will be supported by the green certificates. Looking at new investments however, the picture is somewhat different. As previously discussed, wind power is assumed to represent the major source of new capacity for "green" electricity generation. Due to the high wind speeds along the coast, investments in wind power will be cheaper in Norway than in Sweden. Thus, Norwegian wind power plants would become the major target for green electricity investors. Only in the long-term perspective, wind power capacity would increase in Sweden as well.

Green certificates and emission reductions

In addition to a more diversified energy system ensuring the security of supply, another main argument why increase the share of renewable energy production is to reduce the emissions of greenhouse gasses (GHG) . “Green” electricity will, however, only reduce GHG emissions if it substitutes electricity generation from other polluting energy sources. In Norway, where as much as 99 % of the electricity generation comes from “clean” hydro power, this substitution will certainly not happen with “conventional” electricity consumption domestically. Either, the additional electricity from the new wind power would have to be consumed in other sectors, such as transportation or the oil field, or it would have to substitute “dirty” production in other countries. The former option implies an electrification of the Norwegian oil field, which has long been a demand from environmentalists in Norway. The latter rises the question of cross-country transmission capacities. Critiques in Norway claim that there is no use in increased wind power capacity unless radical investments are also made in the electricity grids. Neither of these issues will be discussed further here, but are left to second thoughts of the reader.

In addition, Golomek and Hoel (2005), Söderholm (2008), Morthorst (2000) and others argue that together with a tradable emission certificate scheme, like the one already existing in the European Union, the introduction of green certificates will *not* lead to increased CO_2 reductions. This is because the power sector is included in the EU ETS and thus reduced emissions from this sector will only lead to a lower price on the emission permits, allowing increased emissions in for instance the industry sector. Thus, the introduction of a green certificate system might help to reach national goals regarding the share of renewable resources employed, but this does not necessarily result in an overall GHG emission reduction.

Conclusion

As this paper has shown, green certificates can be an efficient tool for subsidizing existing and new renewable resources. Being technology-neutral and market-driven, they will support the cheapest producers first and efficiently reach a pre-defined share of “green” electricity in the market. If more countries create a common certificate market further efficiency can be reached through trade of certificates, where the country with the cheapest “green” production will be a net exporter of certificates.

The implications for the different market participants has also been discussed, indicating that this is not necessarily as simple as it might seem. The consumer price is strongly dependent on the level of the “green” quota set by the government. Some models show that if this is set lower than to 25 %, the result might even be a lower consumer price and increased electricity consumption. A lower electricity price will squeeze out some of the existing producers on the conventional market, whereas the remaining producers indirectly will subsidize the “green” producers.

With the introduction of a common Swedish-Norwegian certificate market, probably from 2012, the support will primarily go to Swedish biomass in the short and medium run. Thereafter new investments will be sourced to Norwegian wind power, representing an enormous potential along the long Norwegian cost.

Thus, with a sufficiently high quota and a well-defined regulation (common price ceilings and –floors, corresponding definitions of producers eligible of support, the possibility of banking the certificates etc) Norway might enter an efficient certificate market with Sweden, reducing the public expenses substantially and providing investment support for Norwegian wind power.

Some political challenges remain however, weighting local costs and benefits against national goals of increased “green” electricity production. The question remains why Norway, with 99 % of its electricity produced from hydro power, would have such a goal in the first place. If the reason is reduced greenhouse gas emissions, the effectiveness of green certificates is questionable. Electricity trade with EU countries employing the EU ETS scheme for emission trading means that this development will *not* contribute to overall reduced emissions. Renewable energy sources will nevertheless play an important role in the future energy systems, and Norway might have a strong interest in following this development. If Norway wants to keep the lead as an environmentally friendly energy-nation, now might be the time to invest.

Appendix I

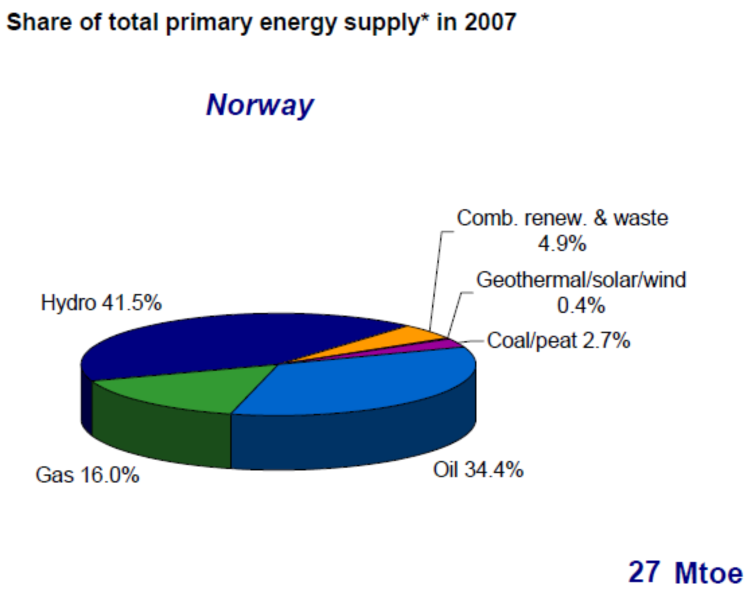

Figure 2: Share of total primary energy supply in Norway in 2007. Source: The International Energy Agency

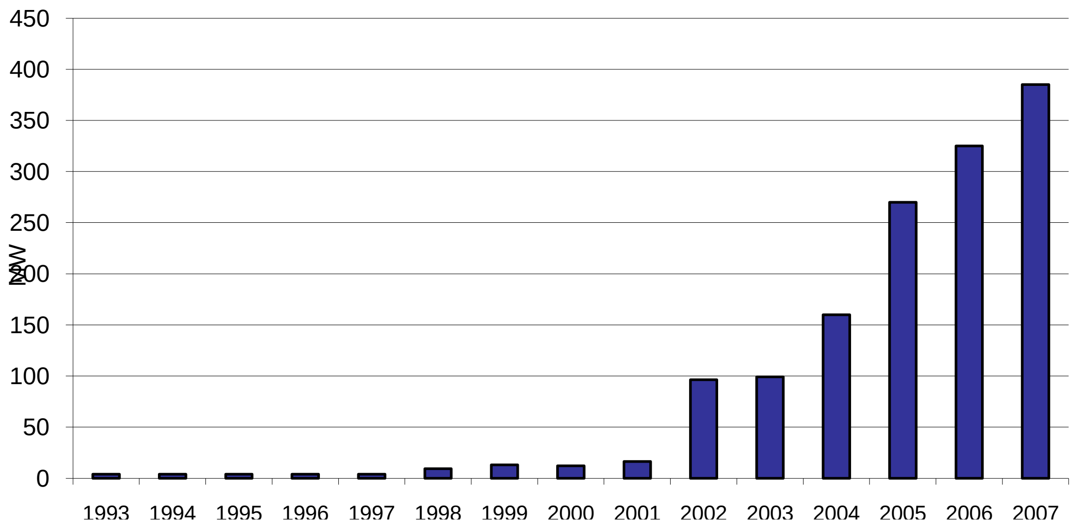

Figure 6: Installed Wind power capacity in Norway from 1993 to 2007. Source: Norwegian Water Resources and Energy Directorate

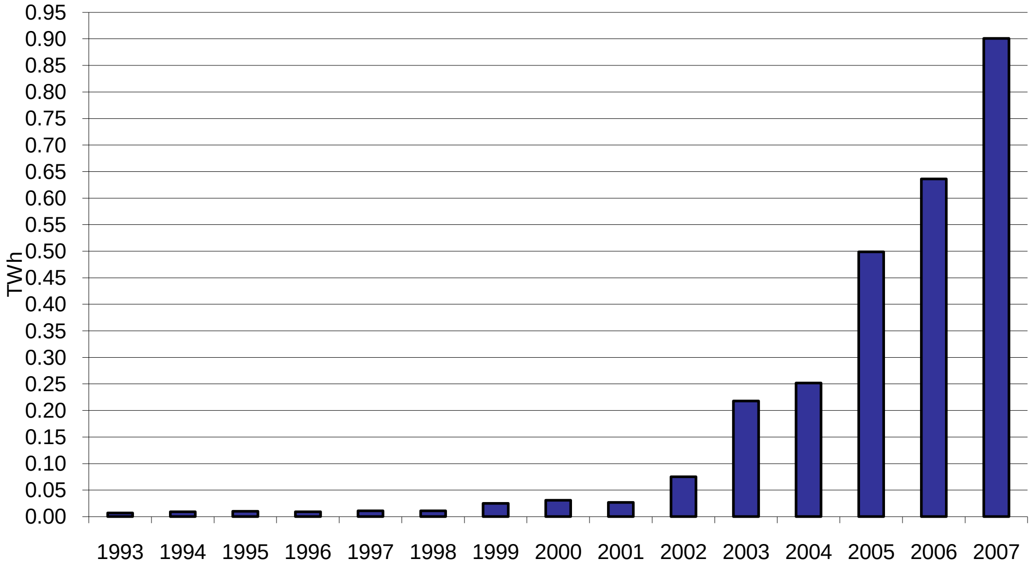

Figure 7: Yearly Wind power generation in Norway from 1993 to 2007. Source: The Norwegian Water Resources and Energy Directorate

Country	% Of final energy in 2005	% Target for 2020
United Kingdom	1.3	15
Denmark	17	30
Ireland	3.1	16
France	10.3	23
Germany	5.8	18
Italy	5.2	17
The Netherlands	2.4	14
Spain	8.7	20
Greece	6.9	18
Belgium	2.2	13
Austria	23.3	34
Portugal	20.5	31
Cyprus	2.9	13
Luxembourg	0.9	11
Malta	0.0	10
Finland	28.5	38
Sweden	39.8	49
Slovenia	16	25
Hungary	4.3	13
Lithuania	15	23
Poland	7.2	15
Slovak Republic	6.7	14
Latvia	34.9	42
Estonia	18	25
Czech Republic	6.1	13
Bulgaria	9.4	16
Romania	17.8	24

Figure 8: Proportion of renewable energy from final energy in 2005 and targets for 2020. Source: CEC 2008, Annex I, reproduced in Toke (2008)

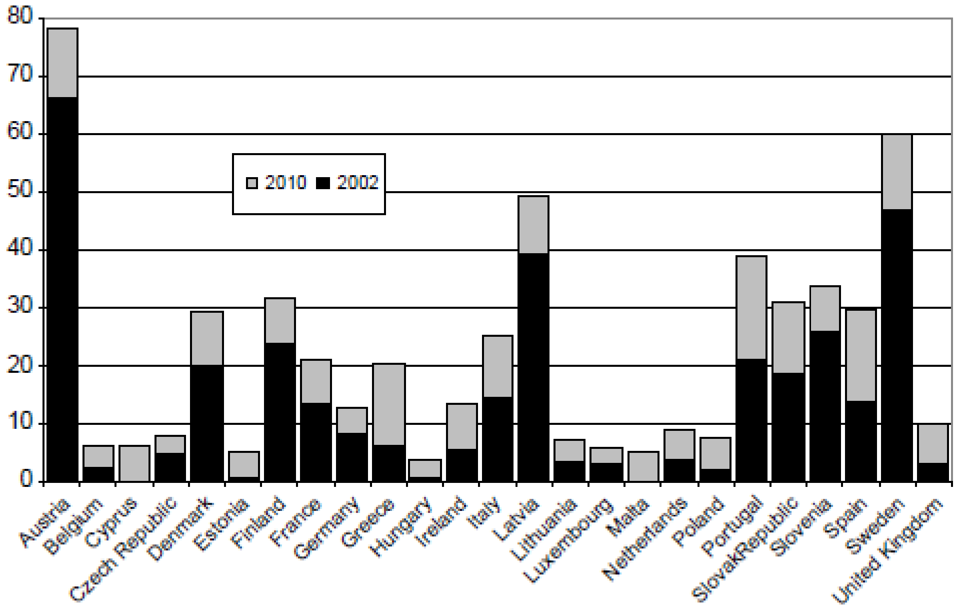

Figure 9: Comparison of percentage share of renewables in power consumption (2002) with EU aim for 2010. Source: Eurostat, 2005, reproduced in Ringel, 2006

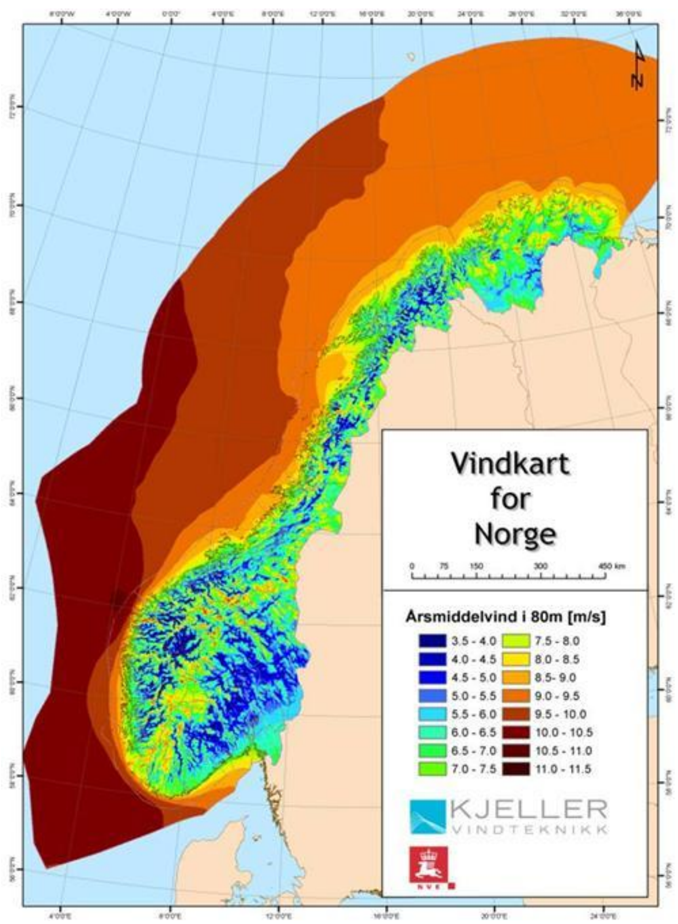

Figure 10: Yearly mean wind in 80 m height. Source: fornybar.no

Appendix II

Country	Year	Energy sources	Calculation of guaranteed minimum feed-in prices	Maximum capacity for partici-pation
Austria	1998–2001	All renewable energy sources (incl. biomass)	Fixed tariffs, decided on by the federal states	No limit
Denmark	1992–1999	All renewable energy sources (incl. biomass)	Wind: 85% of average end user price (plus fixed subvention in form of tax credit)/varying remuneration according to energy source	No limit
France	2000	All renewable energy sources (incl. biomass)	Avoided external costs plus investment grant. Price varies according to energy source	12 MW
Greece	1994	All renewable energy sources (incl. biomass)	70% of average end user price for customer generation/90% of average end user price for independent power producers. Price varies according to energy source	50 MW, hydro 5 MW
Italy	1992–2001	All renewable energy sources	First 8 years: avoided external costs plus investment grant/after 8 years: avoided external costs. Price varies according to public/customer generation	no limit
Luxem-bourg	1994	All renewable energy sources (incl. biomass)	Absolute prices varying according to production capacity and resource type	1,5 MW
Portugal	1988	All renewable energy sources (incl. biomass)	At least 90% of average end user price in the year of generation plant installa-tion	10 MW
Spain	1994	All renewable energy sources	Avoided external costs. Prices vary according to energy source and gener-ation plant capacity.	100 MW
Sweden	1996–2002	All renewable energy sources	Average end user price, minus 'appro-priate' administrative costs and margin	1,5 MW

MW, megawatt.

Tabel 1: Summary of feed-in regulations in various EU member states. Source: Busch PO, 2003, reproduced in Ringel, 2006.

Country	Year	Demand stimulated by	Excepted sources	Maximum price limit	Sanctions	Validity	Tradable on European level
Austria	2002	Quota for consumers (non tradable)	n.a.	n.a.	n.a.	n.a.	n.a.
Belgium	2001	Quota for producers	Waste incinera-tion	Implicit limit given by fixed sanction fees	2004: 12 Ct./kWh fine to regulations authorities	2 years	Regionally limited except bilateral agreements
Den-mark	2004/2005	Quota for consumers (20%)	Large hydro > 10 mwh, waste	Implicit limit given by fixed sanction fees	0,27 DKK/kWh (=3,63 Ct.) fine to fund for renew-able energies	Unlimited	Foreseen with limits
Italy	2001	Quota for producers	Pump water storage	–	Denial of access to transmission grid	2 years	Yes (in com-bination with physical power impor-tation)
Nether-lands	2001	Voluntary	Hydro, waste	n.a.	Loss of tax deduction possibility	n.a.	Yes
Sweden	2003	Quota for producers and consumers	Large hydro	n.a.	n.a.	n.a.	Yes
UK	2002	Quota for producers 5% (2003), 10% (2010)	Large hydro > 10 mwh, waste	Implicit limit given by fixed sanction fees	0,03£/kWh (ca. 5 Ct./kWh)	Unlimited	Treated individually

n.a., not available.

Tabel 2: Summary of the various national green certificates models' features in EU countries. Source: Ringel, 2006.

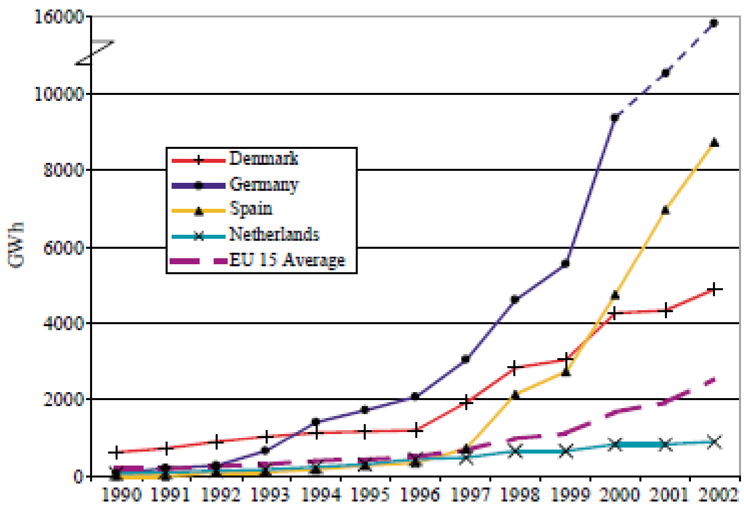

Figure 11: Development of wind power in various EU countries from 1990 to 2002. Source: Eurostat, 2005, reproduced in Ringel, 2006.

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