ELSEVIER

Energy Policy 34 (2006) 1209–1220

ENERGY POLICY

www.elsevier.com/locate/enpol

Renewable electricity in Sweden: an analysis of policy and regulations

Yan Wang*

International Department, Chinese Business Law Firm, 20E, Building 2, International Friendship Garden, Zuojiazhuang A2, Chaoyang District 100028, China

Available online 13 December 2004

Abstract

This study aims to analyse the developments in renewable energy policy making in Sweden. It assesses the energy policy context, changes in the choice of policy instruments, and provides explanations behind policy successes and failures. Swedish renewable energy policy has been developing in a context of uncertainty around nuclear issues. While there has been made a political decision to replace nuclear power with renewables, there is a lack of consensus about the pace of phasing out nuclear power due to perceived negative impacts on industrial competitiveness. Such uncertainty had an effect in the formulation of renewable energy policy. Biomass and wind power are the main options for renewable electricity production. Throughout 1990s, the combined effect of different policy instruments has stimulated the growth of these two renewable sources. Yet, both biomass and wind power are still a minor contributor in the total electricity generation. Lack of strong government commitment due to uncertainty around nuclear issues is a crucial factor. Short-term subsidies have been preferred rather than open-ended subsidy mechanisms, causing intervals without subsidies and interruption to development. Other factors are such as lack of incentives from the major electricity companies and administrative obstacles. The taxation system has been successful in fostering an expansion of biomass for heating but hindered a similar development in the electricity sector. The quota system adopted in 2003 is expected to create high demand on biomass but does not favour wind power. The renewable energy aims are unlikely to be changed. Yet, the future development of renewable energy policies especially for high-cost technologies will again depend strongly on nuclear policies, which are still unstable and might affect the pace of renewable energy development.

Keywords: Renewable energy policy; Renewable electricity; Green certificate; Swedish energy policy

1. Introduction

There have been considerable changes in the production mix of Sweden's electricity sector over the last 30 years. Up until the end of the 1970s, Sweden was dependent to a large extent on oil. Following the oil crises in early 1970s, Sweden developed a nuclear power program and diversified its fuel base into gas, coal, and, since the 1990s, increasingly biomass. Today, hydro and nuclear dominate the power generation mix with 46% and 45.7% of the electricity production, respectively in 2002. Fossil- and biofuel-fired generation accounted for 7.9%. Future expansion of hydropower is, however, limited by the legislated protection of the few remaining large rivers. Nuclear power currently faces an uncertain future. In 1980, a referendum voted for the phase-out of nuclear power. It was this replacement of nuclear power that was the rationale behind renewable energy programs in Sweden. Since 1991, policies have been adopted specifically to promote renewable energy sources. Wind power, despite its high growth rates in the past decade, is still a minor contributor accounting for 0.4% of the total electricity generation in 2002 (SEA, 2003c). The use of biomass in total energy supply has increased by 44% between 1990 and 1999, amounting to 85 TWh in 1999, equivalent to 14% of the total Swedish energy supply (Johansson, 2002). However, the use of biomass in electricity production only increased slightly. In 2002 it was 6.2 TWh (SEA, 2003e) and the corresponding

*Tel./fax: +86 1084544889.
E-mail address: yanjun9@yahoo.com.cn (Y. Wang).

0301-4215/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enpol.2004.10.018

electricity production was 3.8 TWh, which accounted for 2.6% of the total electricity generation.

This study reviews renewable electricity development in Sweden, focusing on policies that have been enacted to promote renewable electricity. Section 2 of the paper discusses background of the Swedish energy policy including nuclear issues, structure of the electricity sector, the principal resources for electricity production and potential of renewable sources. Section 3 describes government policies and regulations that have been used to promote renewable electricity. Section 4 discusses the effectiveness of the various policies and regulations in promoting renewable electricity, as well as barriers to the development of renewable sources. Section 5 discusses other factors that have driven the development of renewable electricity. The final section presents concluding comments.

2. Background—energy policy context

2.1. Nuclear issues

It has been argued that Swedish energy politics and resulting policies cannot be understood without reference to the central role played by nuclear power and the conflicts surrounding it (Vedung, 2001). The exploitation of renewables in Sweden does not have the same direct relation to CO_2 policies as in most other countries, as the current Swedish electricity supply system is based on nuclear and hydropower, which are basically carbon free. Rather, the most direct connection is with nuclear power policies.

Nuclear power has been controversial in Sweden for decades. Following the oil crisis in early 1970s, Sweden had a rapid expansion of nuclear power to reduce its dependence on oil. The expansion of the nuclear industry started with the construction of Sweden's first reactor—Oskars-hamn 1 in 1972. Since then, 12 more reactors have been constructed. However, the Three Mile Island accident triggered the 1980 referendum on nuclear power and on basis of the referendum, the Swedish Parliament decided in 1980 to aim for a shut-down of all reactors by 2010.

Decommissioning of nuclear power would require new sources of energy. It was this replacement of nuclear power that was the rationale behind renewable energy programs in Sweden. However, policies around nuclear issues have not been consistent. Throughout the 1990s, decisions have been made about closing reactors and decisions have been revoked, mainly motivated by the perceived negative impacts on industrial competitiveness that could result from higher electricity prices (Nilsson et al., 2004). In 1997 the Swedish Parliament adopted a new energy program explicitly abandoning the 2010 target.[1] This is still the case after the 2002 agreement[2] in the parliament on the pace of nuclear power decommissioning (Helby et al., 2004). Despite of the 1997 decision to decommission two reactors in 1998 and 2001, so far only one reactor has been closed down—Barsebäck 1 in 1999.

The economic interests and rationalities have much influenced nuclear power policy in Sweden. Support for nuclear power from energy-intensive industry has been strong since turning to biomass instead of nuclear power could lead to increased electricity prices (Nilsson et al., 2004). In January 2003, exceptionally cold winter weather strained power capacity and raised electricity bills, which sparked a new discussion in Sweden on whether to close down Barsebäck 2 as planned. The result of the debate is that the Government has decided to prolong Barsebäck 2's lifetime.[3]

The decommissioning policy still stands, but there is still a basic lack of national consensus concerning the timeframe of phasing out nuclear power. Government negotiations with the nuclear power industry are still going on and future governments might well reverse the present decommissioning policy. In that case, there would be little need for any large-scale conversion to renewables.

2.2. Structure of the electricity sector

Competition was introduced into the Swedish electricity market in January 1996. Since then, all end-users are free to choose their electricity suppliers. The liberalization of the Swedish electricity market provides straightforward access for small independent generators to be connected to the grid.

At the same time market liberalization has also led to more mergers and acquisitions with a trend of an increasing dominance of the biggest electricity companies. There are around 30 electricity companies and in 2002 the five biggest electricity companies had a 90% share of Sweden's electricity production. More and more electricity companies are acquired by companies with their head offices located outside Sweden and the foreign ownership is now 42% (Swedenergy, 2004). However, the biggest electricity company Vattenfall remains as state owned.

The major electricity companies in Sweden all have a significant share of nuclear capacity. Some of them also had an ambition to build new hydroelectric plants (Kåberger, 2003a). Thus, the major interests of these

[1] Prop. 1996/97:84.

[2] Prop. 2001/02:143.

[3] The most powerful industrial organizations have been strongly supportive of nuclear power (Kåberger, 2002a). Energy-intensive industry complained about high electricity costs and pro-nuclear lobbyists said that Barsebäck 2 could not be closed down and Barsebäck 1 should be reopened (Peltola, 2003).

Table 1
Electricity generation by energy source in Sweden in 1990, 1996–2002 and forecast for 2010, TWh

	1990	1996	1997	1998	1999	2000	2001	2002	2010
Hydro power	71.4	51.2	68.2	73.8	70.9	77.8	78.6	66.0	68.6
Wind power	0.0	0.0	0.2	0.3	0.4	0.5	0.5	0.6	3.9
Nuclear power	65.2	71.4	66.9	70.5	70.2	54.8	69.2	65.6	63.6
Conventional thermal power	5.1	14.0	10.0	10.1	9.4	8.9	9.6	11.2	11.8
Total:	141.7	136.6	145.3	154.7	150.9	142	157.9	143.4	147.9

Source: (SEA, 2003c).

companies are in conflict with the rationale and objective of the renewable energy programs.

In addition, under the situation with sufficient, cheap electricity from nuclear and hydropower, most of the big electricity companies did not see the point in developing renewable energy.[4] There are only a couple of countries using more hydropower per capita than Sweden. At the same time more electricity is produced per capita by nuclear reactors than in any other country in the world.[5] Following the market liberalization was a falling electricity price.[6] As a result all nuclear reactor companies published production costs well above the market price (Kåberger, 2002a). From an economic point of view it does not make sense to build new electricity production capacity when there are sufficient and cheap electricity, especially in consideration that the cost of building a renewable electricity production plant is much higher.[7]

2.3. Resources currently used for electricity production

The share of electricity generation from various sources in selected years between 1990 and 2002 is shown in Table 1.

Sweden has more than 700 large hydropower stations, each with an installed capacity of more than 1.5 MW. In addition, there are also around 1200 small hydropower stations that together generate around 1.5 TWh of electricity (SEA, 2003c). Per capita, Sweden consumes more nuclear energy than any country in the world (Kåberger, 2002a). Both nuclear and hydropower were influential in Sweden's energy economy during the last decades. The electrical energy generated by nuclear and hydropower in 2002 accounted for nearly 92% of the total electricity generation in Sweden (SEA, 2003c).

Table 2
Electrical energy generated in 2002 in conventional thermal power stations in Sweden, classified by fuel, TWh

Biofuel, peat, etc.	3.8
Coal	2.3
Natural gas	1.2
Fuel oil	3.4
Others	0.5
Total	11.2

Source: (SEA, 2003c).

The electricity generated in 2002 by conventional thermal power amounted to 11.2 TWh, about 7.9% of the total electricity generation during the year. Power is generated in combined heat and power (CHP) stations, condensing power stations and gas turbine stations.[8] The fuels used are coal, fuel oil, natural gas, peat and biofuels. In 2002, biofuels and peat were used for generating about 3.8 TWh of electricity. Table 2 shows the electricity generated and the share of different fuels in conventional thermal power plants in 2002.

Wind energy is the fastest growing renewable electricity resource in Sweden. In May 2001 there were 534 wind power units. The number of wind power plants has steadily increased and there were a total of 620 wind power plants at the end of 2002. The contribution of wind power to the electrical energy generated in 2002 was 0.6 TWh, an increase of 20% on 2001, and accounted for 0.4% of the total electricity generation in 2002 (SEA, 2003c). Figures in Table 1 show the

[4]For international comparison of electricity prices, see Åstrand and Neij (2004).

[5]The earlier over-investments in nuclear reactors may be understood from the context of individually rational responses conditioned by economic situations and interests. Electricity intensive industry had an interest to provide exaggerated estimates of future energy demand in order to create over capacity, and thereby to get low electricity prices. The managers of the power companies did not critically analyze their figures because the resulting projections fitted their aims so well. The projections justified the idea to build large numbers of reactors to bring down investment costs, and the rapid demand growth showed that renewable energy was not sufficient. The above rationalities had been turned into government policy and resulted in the over-investments in nuclear reactors (Kåberger, 2002a).

[6]The price was for the 3 years (1998–2000) around 0.12 SEK/kWh (Kåberger, 2002a).

[7]For cost of electricity generation with different energy resources, see Åstrand and Neij (2004).

[8]CHP stations are power stations that generate both electricity and heat for supplying neighbouring district heating networks or industrial processes. Condensing power stations are fuelled mainly with fuel oil and uranium and generate only electricity. Condensing power is also generated in CHP stations with recoolers. A gas turbine station is basically a "jet engine" that drives a generator. The fuel used in Sweden is mainly light fuel (SEA, 2003c).

steady increase of energy generation by wind power in recent years.

2.4. Potential for renewable sources of electricity

Despite of the fact that Sweden has rich water resources, future expansion of hydropower is, however, limited due to the legislated protection of the few remaining large rivers. Small hydro is controversial because of environmental impacts in the small streams concerned. Thus biomass and wind power are clearly the most important renewable sources of energy in Sweden so far in terms of resources, policy efforts and impact.

Wind power is one of the main options for renewable electricity production for Sweden. In recent years there has been more focus on identifying concrete sites for onshore and offshore wind power. In a report from the Swedish Energy Agency, it is concluded that the potential may be around 100–200 TWh/yr (SEA, 2001). A large share of the potential production will have to come from offshore installations, considering conflicts of interests for land-based wind power (SEA, 2003b).

Sweden has the second largest peat resources in Western Europe (after Finland) as well as the second largest forest in Europe (after Russia) (Davidsdottir, 2003). Largest sources of biofuels come from forests and peatland areas. These fuels are mainly indigenous, consisting of wood fuels (logs, bark, chips and energy forest), black liquors in pulp mills, peat, refuse, straw and energy grasses. It is estimated that, by 2010, the potential for the use of biofuels in Sweden will be about 160 TWh (SEA, 2003g).

Electricity production from solar PV is negligible in today's Swedish energy system. Except for some programs for R&D on PV, Sweden lacks market development initiatives and subsidy programs such as feed-in-tariffs or roof-top-programs that have led to a direct promotion of PV in countries such as Germany and Japan (Malmkvist and Adsten, 2004) However, the interest from the industry, architects and building companies to integrate solar PV systems in buildings are growing and awareness of the advantage with PV system is getting more well known (SEA, 2003b).

3. Policies for promotion of renewable energy

Policies whose specific goal is to promote renewable energy fall into three main categories: (a) price-setting and quantity-forcing policies, which mandate prices or quantities; (b) investment cost reduction policies, which provide incentives in the form of lower investment costs; and (c) public investments and market facilitation activities, which offer a wide range of public policies that reduce market barriers and facilitate or accelerate renewable energy markets (Beck and Martinot, 2004).

In Sweden, measures taken to promote renewable energy are mainly through investment subsidies, subsidies for research and technology demonstration, tax policies including emission taxes and tax relief for renewable energy. In 2003 quantity-forcing policies (quota systems) were adopted by implementing a system of electricity certificates.

3.1. Introduction—policy development and objectives

The basic line of current Swedish energy policy comes from a set of energy policy guidelines adopted by the Parliament in 1991, according to which, the energy system was to be reformed through the development of cleaner, more environmental-friendly technology for electricity supply and consumption. Investment subsidies for biofuels and wind power were introduced. At the same time tax reform started and environmental taxes were international.

The 1991 policy guidelines were reconfirmed in the 1997 Energy Act[9] that set up the "energy policy program" (*energipolitiska programmet*) from 1998. The program has two principal components: a 7-year extension of the previous energy research programs and a 5-year short-term program of subsidies measures. An overall objective of the short-term program was to meet the conditions for closure of the Barsebäck 2 nuclear reactor by compensating for the loss of 3 TWh of nuclear electricity production with electricity produced from renewable energy resources, and with a decreased use of electricity.

However, an evaluation of the short-term program has indicated the need for a somewhat different approach to promote the development of renewable electricity. The Government felt that targeted support to individual technologies or sources of energy could distort competition and thwart technological development. It thus concluded that a general system of support would reduce such distortion since the renewable sources of energy have to compete with each other on equal terms (MOI, 2002).

Therefore, following the Energy Act adopted by the Parliament in 2002, a new mechanism—a system of electricity certificates trading was introduced to replace the short-term measures. The objective of the new regulatory mechanism is to promote a new and more long-term orientation both for encouraging power generation from renewable sources and for more efficient energy utilization.

The Parliament has also set a target for the increase of consumption of electricity from renewable resources by 10 TWh from 2002 to the year 2010. Furthermore,

[9] Prop. 1996/97:84, En uthållig energiförsörjning.

transitional support measures are retained for wind power and a national target for wind power has been set to be 10 TWh by the year 2015. The following will have a detailed discussion of the above mentioned policy measures.

3.2. *Investment subsidies*

Direct investment subsidies have been a preferred form of subsidy to renewables in Sweden. It provides the security for investors as it decreases both financial barriers and costs. Direct investment subsidies have also allowed government to maintain a firm control. Once the allocated funds were used up, there would be no more subsidized activity, until a new political decision was made. This also related to the fact that investment subsidies have often been granted as part of political horse-trading. Parties not favourable to renewables have preferred to accept subsidies that were clearly limited in amount and time, rather than accepting open-ended subsidy mechanisms (Helby, 1998).

The 1991 energy policy marks the start of investment subsidies for wind power and biomass-fuelled CHP. Investment subsidies were reactivated in the 1997 short-term program, but with a certain percentage of reduction from the previous level. Small-scale hydropower was also included in the 1997 subsidy scheme.

3.2.1. *Wind power*

Investment subsidies for wind power were initially at 25% in 1991 and from 1993 at 35% of the total investment cost. This subsidy system was somewhat unstable. A particular amount of investment subsidies were distributed on a first-come first-serve basis. Then there were intervals with no subsidies, until new funding had been negotiated among the political parties. Through most of 1996 and 1997, no subsidy was available (Helby, 1998). Altogether, the subsidy was granted to the installation of 350 turbines with a total rated capacity of 110 MW (Nilsson et al., 2004).

The subsidy scheme was reactivated in the 1997 short-term program, but at a reduced subsidy level of 15%, and with a limit on the available funds.[10] By 2002, altogether 374 wind turbines (290 MW) were installed under this subsidy scheme (Nilsson et al., 2004). However, most of these subsidies expired on December 30, 2002. Transitional subsidies to wind power are retained as special measures to promote wind power, which will be further discussed in Section 3.6.

3.2.2. *Biomass-fuelled CHP*

Investment subsidies were also available for plants producing electricity from biomass. The subsidy introduced in 1991 was 4000 SEK/kW of installed electric capacity. To conform to the requirements, the subsidized parts of the plant had to use at least 85% biofuels for a period of 5 years. The funds allocated for this subsidy were exhausted in 1994 (Helby, 1998). Altogether 16 CHP plants received the subsidies (Nilsson et al., 2004). There was no refunding until 1998, when the subsidy scheme was reactivated in the 1997 short-term program, but with a maximum of SEK 3000/kW. From 1998 to 2002, nine CHP plants were established (Nilsson et al., 2004). However, these subsidies expired on December 30, 2002.

3.2.3. *Small-scale hydro*

Until 1998, there were no investment subsidies for small-scale hydro. In 1998 a 15% subsidy was introduced for plants with a capacity between 100 and 1500 kW. The subsidy was available for new plants, as well as for renovations. The renovation of a plant that stopped production before 1997 was regarded as equivalent to investment in a new plant. For renovation of producing plants, subsidy was only given to those parts of the investment that could be shown to increase production (Helby, 1998). These subsidies also expired on December 30, 2002.

3.3. *Tax policy and measures*

Accounting for externalities in the energy equation, and thereby reflecting some of the social costs of energy use, has become an increasingly important aspect of energy policy (Johansson, 2002). Many new approaches to address externalities have emerged in recent years. In Sweden, in addition to investment subsidies, emission taxes and tax relief are used to address this issue.

3.3.1. *Emission taxes*

There are a number of taxes levied on the amount of environmentally hazardous material released, which could reduce the competitiveness of conventional energy fuels and potentially promote the use of renewable energy sources. In Sweden, the taxation of fossil fuels has been gradually increased through the 1990s. They include several forms of taxes, based on either emissions of CO_2, sulphur and NO_x or simply on the amount of energy.[11] In the spring of 2000 the Parliament decided to implement a green tax exchange reform. Carbon dioxide tax was increased, in January 2001, from 370 to 530 SEK/ton and from January 2003 to 760 SEK/ton. It was a successful tax in introducing bioenergy technology and increasing the use of bioenergy sufficiently to bring down the costs of bioenergy (Kåberger, 2002c).

However, carbon dioxide tax is only levied on fossil fuels used in heating sectors. Power generation is exempt

[10] The total budget appropriation was 300 MSEK.

[11] Fossil fuel taxes in 1996 were as follows: CO_2 tax: 360 SEK/ton; sulphur tax: 30 SEK/kg; NO_x tax: 40 SEK/kg (Helby, 1998).

Table 3
Supply of fuel in electricity production, 1990–2002, GWh

	1990	1995	1996	1997	1998	1999	2000	2001	2002
Oil	1531	5225	12666	5344	4970	4208	3273	3202	4488
LPG	279	406	251	276	250	306	323	286	0
Natural gas	464	758	651	681	583	543	515	418	687
Biofuels	2454	3338	3349	3908	3954	3532	4913	4676	6198
Coal, etc.	2378	3758	7290	3695	4361	4317	3657	4448	4589
Total	7107	13485	24207	13903	14118	12906	12680	13030	15962

Source: (SEA, 2003e).

from carbon dioxide tax, which has led to a high proportion of fossil fuels in power generation (see Table 3). Low electricity prices in the deregulated electricity market, together with the unfavourable tax system for biomass-based electricity have resulted in hesitation among the investors (SEA, 2003f). Thus the biomass-based electricity production only increased slightly while there has been a rapid increase of biomass use in heating sector since 1991.[12] The main consideration for this arrangement in the tax system is as follows: A CO_2-tax on fuels would tend to move electricity production abroad, to neighboring countries with no such tax. Any attempt to impose a compensating tax on power imports would be against EU-rules. Therefore, a CO_2-tax might be ineffective or even counterproductive from a transnational perspective (Helby, 1998).

Generation in nuclear power plants is subject to a power tax on the thermal power of the reactor, at a rate amounting to 5514 SEK/MW per month. In addition, there is a levy of 1.5 SEK/MWh to cover the costs of waste management from earlier nuclear research at the Studsvik research centre and a further levy of about 10 SEK/MWh for financing future storage of used nuclear fuel (SEA, 2003c). According to a government commissioned report, the sum is not sufficient to cover all possible costs.[13] To get a large-scale breakthrough for new renewable sources of electricity, subsidies are not sufficient. Instead the subsidies of conventional non-renewable energy should be removed and the external costs of the systems be internalised (Kåberger, 2003b).

[12]The use of biomass in district heating was 10.4 TWh in 1990 and reached to 33.0 TWh in 2002 (SEA, 2003e).

[13]Cost estimates were so uncertain that there was a need to have the industry provide reliable paying capacity to cover at least the potential management costs in the new century. As these costs were uncertain they could not easily justify further fund accumulation, beyond the planned costs. Instead the industry was supposed to provide economic securities that could be used if real cost became larger than the planned costs already covered by money accumulated in the fund. [Reported in SOU 1994:107/108] (Kåberger, 2003b).

3.3.2. Tax relief for renewable energy sources

Since 1994, small-scale electricity production based on renewable energy sources is partially or totally exempted from the energy tax. This gives a tax benefit of 1–2 ct/kWh. This is beneficial for small-scale electricity producers.

A special arrangement has been made for wind power. The end-user tax on electric power is refunded to these producers as an "environmental bonus". As the end-user tax on electric power has been gradually increased in the last years, this has meant a gradual increase in incentives for wind power (Helby, 1998). Currently this bonus is equal to the electricity tax (1.81 ct/kWh).

3.4. Subsidies for renewables R&D

Renewable energy was an item on the agenda right from the start in the first Energy Research Program in 1975–1978. Wind energy and biomass have been prominent in all subsequent energy research programs. The 1997 Energy Act also contained a 7-year long-term energy RD&D program[14] to run in the period 1998–2004, with a volume of SEK 2.31 billion. It covered CHP and power from biomass, large scale and off shore wind power, and PV. The all-round goal of the RD&D program was to reduce the costs, and introduce new energy technologies, for renewable energy and energy efficiency.

One important difference in the Swedish R&D system compared to other European countries is that Sweden has developed only a small number of industrial research institutes. Instead, the universities are given the task of providing more applied research and industrial collaboration. In order to strengthen this so-called third pillar of the Swedish university system, a number of "hubs" or "Centres of Competence" were established. There are currently five energy-related centres of competence, focusing on catalysis, electricity, high-temperature corrosion, combustion engines and combustion technologies, respectively.

[14]Research development and demonstration programs.

The recent evaluation of the RD&D part of the 1997 program concludes, however, that there was probably too much faith in the possibility of energy RD&D to drive the transition of the energy system. On the whole, per capita spending on energy RD&D has been relatively high in Sweden and with a stronger focus on energy efficiency and renewable energy than in most other IEA countries (Nilsson et al., 2004). Sweden has become a world leader in many areas of energy research and in the development of energy technology. The problem is that the results are not converted into products and services in the market to the desired extent. Ultimately, this is a question of increasing the pace of the transformation of the Swedish energy system and of increasing growth in Sweden. Therefore in 2003 the Swedish Energy Agency started two pilot projects aiming to develop working methods that could help increase the rate at which research results are commercialised (SEA, 2003d).

3.5. Quota system—electricity certificate

Under the quota systems, governments set political targets—typically by mandating a minimum share of capacity or generation to come from renewables—and let the market determine prices through certificate markets and/or bidding systems (Johansson, 2002).

The quota system was introduced in Sweden on 1 May 2003 through a system of electricity certificates trading. Under the system, the producer sells the electricity that is produced in the ordinary way in the electricity market and receives revenue for the sale. The certificate that the producer receives from the State can also be sold and in this way provide extra revenue. Therefore, producers of electricity based on renewable sources of energy receive revenues both from the sale of electricity and from the sale of certificates.

The advantage of such a system would be the elimination of the subsidies from the state budget and the introduction of competition between different producers of electricity from renewable sources which in turn is expected to reduce the total costs of the system.

As this system is designed to promote investments in the least-cost renewable electricity sources, it is not particularly well suited to promoting new, yet uncompetitive, technologies such as wind and PV technologies. For Sweden, this is expected to result in more biomass-based CHP whereas the development of wind power may be temporarily slowed down. Targeted support for technology development and market introduction of offshore wind parks and wind power in the mountainous regions has been introduced to compensate for this effect, as will be illustrated in Section 3.6. The following will explain some basic elements of how the certificate trading system works.

3.5.1. Scope of application

According to the Electricity Certificate Act, the following renewable sources of energy are entitled for the allocation of electricity certificates: wind power, solar power, geothermal energy, biofuels, wave energy and hydropower. For hydropower, certain requirements have to be met.[15] Peat was later included in the electricity certificate system according to a new government bill in 2003.[16]

3.5.2. Issuance and administration of the certificates

The certificates are issued and allocated monthly in arrears by Svenska Kraftnät (2003) (Swedish National Grid). They do not exist as hard copies, but only virtually in a certificate register maintained by Svenska Kraftnät. The register will be on a database. Every generator or rather one or more of the owners entitled for the certificates will have a certificate account with an optional number of subsidiary accounts, for example one for every plant (SEA, 2003a). In connection with every monthly statement, new certificates are transferred to the plant owner's account.

3.5.3. Quota obligation

The system is based on a legal requirement on the consumer or the electricity distributor to buy an amount of certificates equivalent to a certain fraction of their electricity consumption. This is known as the quota obligation. The quotas are set in order to increase the production of electricity from renewable sources by 10 TWh from 2003 to 2010. The first year was 2003, when electricity suppliers and users were obliged to buy seven certificates for every hundred MWh they used (SEA, 2003a). The quota will then be increased from year to year in order to stimulate investments in power generation from renewable energy resources. The electricity-intensive industry is exempted from any compulsory quotas. The argument for this is that there are no such demands on their competitors in other countries.

[15]The following requirements should be met:

- it is in operation and has an installed generation capacity of a maximum 1500 kW at the end of April 2003;
- it was decommissioned before 1 July 2001 and then recommissioned after the end of 2002;
- it was commissioned for the first time after the end of 2002;
- it increases its production of electricity;
- due to a decision by an authority, it no longer can maintain long-term profitable production;
- after extensive reconstruction, it no longer can maintain long-term profitable production, and it has an installed generation capacity of a maximum of 15 MW.

[16]Regeringens Proposition (2003/04:42) Torv och elcertificat.

3.5.4. Price guarantee

Unlike most countries that adopt quota systems, Swedish quota system not just stipulates quota obligation, but also sets a guaranteed price for the certificate. In order to provide generators with protection against excessively low certificate prices, a price guarantee for the certificates is given during an introductory period (2003–2007). This means that any electricity certificates, which may not have been sold, can be cashed in during the period from 30 April to 30 June. Each MWh gives one certificate. For certificates being issued 2003, the guaranteed payment will be SEK 60 per electricity certificate and can be cashed 2004 (SEA, 2003a). The price has build-in declines over time and will be phased out entirely in 2008.

3.6. Specific measures to promote wind power

Progress in the field of wind power has been rapid in recent years. Today wind power stations can be constructed in locations that were not previously possible and at lower costs. Nonetheless, new wind power cannot easily compete with existing production in, for example, thermal power stations. As discussed earlier, investment subsidies to wind power expired in December 2002 and the new electricity certificate system is not particularly well suited to promoting new and uncompetitive technologies as wind power. In order to create conditions for a continued positive development in this area, the Government proposed transitional subsidies for wind power production. The environmental bonus (the tax relief of 18.1 cent/kWh) will be retained for a transitional period of seven years, during which it will gradually be phased out. In addition, support is also available for market introduction of wind power technology. The support may be used for technology development and market introduction of large-scale wind power plants (MOI, 2002).

In addition to transitional subsidies, the Government proposed the establishment of a national planning objective for wind power of 10 TWh by the year 2015. The purpose of the planning objective is, inter alia, to make wind power visible in physical planning and in connection with the granting of permits.[17]

A future large-scale expansion of wind power may, in many cases, be located to sea and mountain areas. In order to cut costs for such plants in the long term, the Government proposed to work together with the business sector to implement specific development measures. The idea is to set up plants in different kinds of environment including "difficult areas" like sea and mountain locations in order to gain valuable knowledge for future expansion.[18]

4. Effectiveness of governmental policies and regulations

4.1. Overall assessment

As mentioned earlier, the objective of the 1997 short-term program was to meet the conditions for closure of the Barsebäck 2 nuclear reactor by compensating for the loss of 3 TWh of nuclear electricity production with electricity produced from renewable energy resources, and with a decreased use of electricity. The program expired in 2002 and the Swedish Energy Agency in July 2003 presented a report on the results of the program. It is clear that the objective has been reached. The different targets and the outcome of the program are shown in the table below (Table 4).

Government support on research and development has helped develop new technologies for utilisation of renewable energy. System of investment subsidies for wind energy and biomass-based CHP has been important for bringing these technologies into the Swedish market as it has decreased financial barriers and costs. Wind power plants are getting bigger and more efficient. In 1997, there were 304 wind power plants with a totally installed power of 75,4 MW. In 2001 there was 540 wind turbines with a totally installed capacity of 260 MW in Sweden. And at the end of 2002 there were a total of 620 wind power plants. In the period 1991–2002, the subsidies led to the installation of 25 new biomass CHP plants.

Imposing environmental tax on competing fossil fuels and tax relief for biofuels created conditions for the growth of bioenergy, yet this has been directed mainly at the heat fuel markets. The result was a large-scale, surprisingly successful increase in biofuel use in the heating sector, but a slight increase of biofuel use in electricity generation.

The quota-based certificate system, effective as of 2003, is expected to increase biomass-based electricity production. During the period of May–December 2003, a total of almost 5 million electricity certificates were issued, almost 75% of which were for bio-fuels. Wind power only accounted for 7%. The fact that the electricity certificates favour biofuels has led to greater interest in R&D on how the efficiency of biofuel plants can be increased (SEA, 2003d).

[17] Prop. 2001/02:143.

[18] Examples of issues that could be highlighted are the impact of sea-based wind power on flora and fauna. This initiative might require resources amounting to SEK 350 million for a 5-year period. Prop. 2001/02:143.

Table 4
Objectives for the 1997 short-term energy policy program and the outcome of subsidies allocated until 30 April 2003

	Objective (TWh)	Outcome of decision until 30 April 2003, (TWh)
Reduced electricity consumption	1,5	1,52
Biofueled CHP	0,75	0,88
Wind power	0,5	0,85
Small-scale hydropower	0,25	0,03
Total	3,0	3,28

Source: SEA (2003b).

4.2. Barriers to the development of renewable electricity

Despite of the above achievements, studies also showed that the Swedish effort in monetary terms has produced relatively modest results in terms of installed capacity so far. For example, Germany and Spain have roughly 2–5 times more installed capacity per euro spent on market subsidies and RD&D (Åstrand and Neij, 2004). Much of the difference may be ascribed to the lack of continuity and coherence in Swedish government efforts. The subsidies have lacked continuity and there were intervals without subsidies. The long-term government intentions have not been clear (Nilsson et al., 2004).

The lack of continuity and long-term commitment in Swedish policy is mainly due to the nuclear issues. During the last two decades, the deadlock on nuclear power issues has made it difficult for the government to have a consistent policy. It is essential to try to achieve a consensus on the long-term objectives. The question of phasing out the nuclear power plants has taken up too much time and effort and thus affected the progress of renewable energy development.

The subsidies of conventional non-renewable energy are also barriers to the development of renewable energy sources. Currently in all the countries that have nuclear reactor, regulation of the economic liability for nuclear reactor accidents serves to make the nuclear power profitable by socializing the costs of potential accidents.[19] In Sweden, the introduction of the liability legislation has immediate and significant economic implications for the competitiveness of an energy technology. It was designed to act as a subsidy for nuclear power.[20]

There were discussions about the possibility to find insurance-like solutions to share nuclear accident risks via the international capital market.[21] However, these arrangements were fiercely resisted by representatives of the old, established sources of electricity (Kåberger, 2003b), as such measures would incur costs and reduce their competitiveness in relation to new energy technologies. Thus, the already established cheap nuclear power has effectively blocked any large-scale introduction of renewable energy.

Wind power is one of the most environment-friendly energy sources available and Sweden is well suited for wind power utilization with its sparsely populated, windy coasts and mountain regions. However, wind power development in Sweden is still limited despite of the achievements in recent years. There are several reasons for this.

Sufficient, cheap electricity from nuclear and hydropower is a critical factor. The power industry did not see the point in investing in a new energy system under the current situation with cheap available power.

Second, at the moment there is no strong driving force for Sweden to move to further wind power development, as the current Swedish electricity supply system is based on nuclear and hydropower, which are basically carbon free. The nuclear issue has more or less paralysed the parliament politics and caused inconsistent energy policy. Situation could change in the future with further decommissioning of more nuclear reactors.

The coordination between different levels of government regarding wind power is not well organised, which constitutes another obstacle. This is reflected in the process of issuing permissions for wind power installation in Sweden. As national government commitment to promote wind power has not had enough strength, the reaction of the regional and local government, that are in charge of issuing the permit, is slow.[22]

Complicated legislation and permission procedure have aggravated the situation. There are two laws that regulate the development of wind power with respect to building permissions and environmental conse-

[19]It has two elements. First, in case of a nuclear reactor accident, only the operator can be held liable. Second, the economic liability of the operator in case of a major reactor accident is strictly limited to an amount far below the potential costs of a major accident (Kåberger, 2002b).

[20]In Sweden, the law was based on a government commission that justified this subsidy by arguing, "From the statements above, it is

(*footnote continued*)
necessary to utilize nuclear power—at any cost—if we are to avoid a lowered standard of living" (Kåberger, 2002b).

[21]Operators could be forced to sell catastrophe bonds to collect capital enough to compensate victims of large accidents. Such bonds would loose all their value in case of a reactor accident, and to find voluntary capital the reactor operator would have to pay an extra premium interest on the bonds. By compulsory arrangements of this kind there would be a market value created for nuclear accident risks. And this risk cost would have to be paid by nuclear power operators, reducing their competitiveness in relation to new energy technologies. (Kåberger, 2003b).

[22]Dr. Tomas Kåberger also indicated in a phone interview that there have been cases where some existing power companies lobbied against the building of wind power due to the potential competition from the wind power.

quences.[23] The double regulation resulted in double work for the applicant and relevant authorities (SEA, 2003h). This is not specific to wind power, but also affects other activities which require a permit according to the regulation, including biofuelled CHP.

5. Other factors driving renewable electricity development

5.1. Public concern about the environment and attitude towards renewable electricity

Swedish people generally have a strong awareness of environmental issues. Today there is a political consensus about the protection of rivers, which is much attributed to the environmental movements of the people. There is also strong public resistance towards nuclear power. Although public opposition has not been able to stop the nuclear industry entirely, its expansion has been severely limited.

However, people's opinion on the environment might change with the economic cycles. Between 1988 and 1991 when the Swedish economy slowed down, the number of voters who regarded environmental issue as important decreased from 48% to 26% while the number of voters who regarded the economy as an important issue increased from 13% to 38% (SSNC, 2003). The reason for this change was that environmental actions were regarded as expenses that people could afford only when the economy permitted.

Renewable energy is a concept generally supported by the public opinion. In a recent study, wind power is viewed as an environmentally benign electricity source by 88% of the respondents of the study. Biomass fuelled power is considered to be clean electricity source by 55% of the respondents (EK, 2004). However, although the public generally expresses a positive attitude towards wind power, specific wind power projects face resistance from the local population. Investments in institutional capital might be a productive instrument to reduce problems with local resistance. Such investments can be carried out through promoting a more collaborative approach; for instance by inviting local residents to participate in early stages of the planning and implementation of wind power projects (EK, 2004).

5.2. NGO activities—voluntary scheme of green electricity

The liberalization of electricity market in Sweden has also made it possible for customers to directly influence the way their electricity is made by demanding specific products, especially green power. Following the liberalization in 1996, the Swedish Society for Nature Conservation (SSNC) decided to introduce the label "Bra Miljöval" (Good Environmental Choice) into the electricity market. SSNC is Sweden's biggest nature and environment organization. It has been instrumental in initiating a number of environmental schemes or guidelines.

The objective of the labelling scheme is to speed up the conversion from nuclear power and fossil fuels to renewable energy sources and to prevent the continued expansion of hydroelectric power stations. Only electricity based on renewable types of energy can be Bra Miljöval-labelled. Solar, wind, hydro and biofuel belong to this category. The labelling scheme is based on voluntary agreements. Those who want to use the label or refer to the label must fulfil all the compulsory requirements and enter into a licence agreement with SNNC. The labelling scheme gives utility customers the option to pay a premium on their electric bill to cover the incremental cost of producing electricity from renewable sources.

Market responses to the labelling scheme are different depending on the characteristics of the companies. The major energy companies in Sweden all have a significant share of nuclear capacity. Some of them also had an ambition to build new hydroelectric plants. Thus, the main interests of these companies were directly in conflict with the objective of the environmental labelling scheme. Some of the medium size suppliers that existed at the time, however were clearly interested in contributing to the establishment of a market for environmentally labelled electricity contracts. The number of companies holding a licence to sell environmentally labelled delivery contracts has increased from 11 in 1996 to 54 by the end of 1998. Despite mergers and take-overs reducing the number of companies, the number of licenses increased to 72 by the end of 1999 (Kåberger, 2003a).

Companies have been the main customers of the environmentally labelled electricity. The reasons are that household consumers in practice are still rather inactive on the competitive market, and the public administrations have been held back by fear of legal constraints from the EU directive on public procurement (Kåberger, 2003a). Companies who wanted to reinforce or establish a good environmental image have been the early movers.

The success of the labelling scheme can be partially judged by the amount of sold electricity. It was successful from the beginning. Already in 1996 the amount of sold environmentally labelled electricity reached 4 TWh. Since 1996 the sold amount of electricity increased almost exponentially until the peak in 2001 at 15.4 TWh (Kling, 2003).

[23] Plans for wind power stations must be examined for conformity with two Acts: The Planning and Building Act, SFS 1987:10, and the Environmental Code, SFS 1998:808. Both laws are now under the review of the parliament-appointed committee.

6. Conclusion

Swedish renewable energy policy has been developing and evolving in a context of debate around nuclear issues—the pace of phasing out nuclear power. The debate, no doubt, had an effect in the formulation of legal attitudes to renewable energy, which in turn fashioned legal techniques that were used in the formulation of renewable energy policy and regulations. On the one hand, there has made a political decision to decommission all nuclear reactors and it is this replacement of nuclear power that was the rationale behind the renewable energy policy programs. On the other hand, there are concerns about the negative impacts on industrial competitiveness and thus there is still a basic lack of national consensus concerning the pace and timeframe of phasing out nuclear power.

Such a dilemma resulted in a lack of strong government commitment to developing renewable energy sources, which is reflected in the short-term nature of the subsidy programs for the renewable energy sources. The subsidy programs were limited in amount and time, causing intervals without subsidies and interruption to the development of renewable sources. Thus biomass and wind power, despite of the growth in the past decade, are still a minor contributor in the total Swedish electricity generation.

The successful Swedish experience in promoting biomass use in heating production shows that using the tax instrument is a cost-efficient policy and measure, which can be used to internalise the cost of those external effects and thus promote the use of renewable energy sources. However, environmental taxation on fossil fuels has been directed mainly at the heat fuel markets. Power generation is exempt from carbon dioxide tax. The result was a large scale, surprisingly successful increase in biofuel use in heating sector, but only a slight increase of biofuel use in electricity generation.

The quota system in the form of tradable green certificates, effective as of 2003, is expected to create a firm demand for bio-fuels for electricity production. It is expected to result in more biomass-based CHP as this system is designed to promote investments in the least-cost renewable electricity sources. Thus, the system is not particularly well suited to promoting new, yet uncompetitive, technologies such as wind power. The development of wind power might be temporarily slowed down. Targeted support for wind power has been introduced to compensate for this effect. However they are short-term measures and will be phased out in a few years. Long-term government commitment and support are therefore necessary for the further development of wind power.[24]

There are also legislative and administrative obstacles to the development of renewable energy. As witnessed in the case of wind power development, weak governmental initiative resulted in the slow reaction of the local governments that are in charge of issuing the permit for wind power installation. Double regulation has worsened the situation. This is not specific to wind power, but also affects other activities which require a permit according to the regulation, including biofuelled CHP.

Other barriers are such as subsidies of conventional non-renewable energy, cheap and sufficient electricity from nuclear and hydropower and a lack of incentives from the major electricity companies to develop renewable energy sources. The major electricity companies all have a significant share of nuclear capacity and thus their main interests are in conflict with the rationale and objective of the renewable energy programs.

In addition to the governmental policies and regulations, there are also other factors affecting the development of renewable sources. NGO activities have been important driving force in promoting the renewable energy sources in Sweden. The degree of public opinion on environment changes with the economic cycles. When the economy is regarded as important, the importance of environmental issue decreases, and vice versa.

The renewable energy aims are unlikely to be changed. The green certificate system may become a strong stimulation for the least-cost renewable electricity sources such as biomass. However, the future development of renewable energy policies for the high-cost technologies such as wind and solar energy resources are difficult to predict, and will again depend strongly on nuclear policies, which are still unstable and might affect the pace of renewable energy development.

Acknowledgements

This paper is based on research funded by the Research Council of Norway under the project "Green Electricity for Sustainable Energy Development: A Comparative Analysis of European and US Experiences and implications for Norway", coordinated by CICERO, Center for International Climate and Environmental Research, Oslo. The author wishes to acknowledge the support from CICERO and the Research Council of Norway as well as very valuable comments from Dr. Lin Gan, Professor Fredric Menz and the unknown external reviewer. All remaining errors are the sole responsibility of the author.

[24]It was suggested that it be necessary to also secure other support

(*footnote continued*)
for wind power such as bank loans and investment from institutional investors (interview with Mr. Claes Pile at Ministry of Environment on December 9, 2003).

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