Chapter 18
Sweden

18.1 INTRODUCTION

Sweden has a good wind energy resource, although deployment has previously been slow. However, during the last couple of years deployment and development of wind-power technology have sped up, in accordance with implemented investment subsidy programs. One of the most important factors for wind energy deployment is the economic terms, now being revised, for renewables on the deregulated market.

18.2 NATIONAL POLICY

Sweden's energy policy, as decided by the Swedish Parliament in 1997, is to provide secure short-term supplies of electricity or other energy on competitive terms. The country's energy policy is intended to create conditions for efficient use and cost-efficient supply of energy, with minimum adverse effects on health, the environment, and climate, while at the same time assisting the move towards an ecologically sustainable society.

Considerable challenges face Sweden in the future. The decision to phase out nuclear power, the commitment to reduce greenhouse gas emissions in line with the Kyoto Protocol, and the limitations on further expansion of hydro-power resources give crucial importance to the development and market introduction of alternative energy sources, as well as successful energy-efficiency measures. Wind energy is one of the key elements in the transformation of the power system. During 2002, the parliament decided to establish a planning target for wind power. The target is set at 10 TWh of electricity production from wind power in 2015, provided that economic conditions for wind-power investments are sufficient. The purpose of the target is to remove planning and permission obstacles for the implementation of wind-power plants.

An electricity certificate system will be introduced in 2003 to improve the conditions for electricity from renewable energy on the liberalized electricity market. During 2002, preparations to implement the system were made at the Swedish Energy Agency and Svenska Kraftnät (the utility that owns and operates the national electricity grid).

Strategy

An extensive energy policy program has been started to facilitate the restructuring and development of the energy system. The main thrust of this work is in the form of substantial long-term concentration on research, development, and demonstration of new energy technology.

Over one billion Euros have been allocated to the program, which consists of two parts. The first part lasts seven years and is a research, development, and demonstration program aimed at promoting renewable energy sources, new conversion, and new end-use energy technologies. These long-term efforts will focus on new technology development of bio-fuel fired CHP; bio-fuel supply and ash recycling; new processes for extracting ethanol from forestry raw materials; alternative motor fuels; wind power; and solar and energy efficiency in buildings, industry, and the transportation sector.

The second part of the energy program is to replace the electricity production loss of about 4 TWh from the Barseback nuclear power plant. This part, finalized during 2002,

is a five-year, short-term subsidiary program to promote electricity production from renewable energy sources such as bio-fuels, wind, and small hydro-power plants, and to promote energy efficiency. The wind-power investment subsidy program will, however, continue during 2003 until the resources have been used.

The total cost for the two-part effort is 1.07 billion Euros, of which 0.6 billion Euros are allocated to the long-term research, development, and demonstration program.

The responsible authority for transforming the Swedish energy supply system into an ecologically sustainable system is the Swedish National Energy Agency (SNEA), which was formed on 1 January 1998.

As for wind energy, the government is supporting the development and installation of wind turbines in three programs managed by the SNEA. These problems are as follows.

- A new research and development program with a three-year budget of about 90.00 MSEK for 2002 to 2004. The program is presented in Section 18.8.
- A development and demonstration program for wind systems, with a maximum of 50% support.
- An investment subsidy program operating since 1997 that may receive 10% of the total investment cost. The program's 2002 budget was 100.00 MSEK.

The utilities are engaged in studies, demonstrations, and evaluation projects. Since 1994, the utilities' research and development activities have been coordinated in a jointly owned company, Elforsk AB, which initiates projects and finds sponsors in the field of power generation. In addition to the activities of Elforsk AB, the largest utility, Vattenfall AB has a wind energy development program of its own.

Progress Towards National Targets

The target of the five-year investment subsidy program (July 1997 to June 2002) was 0.5 TWh of wind electricity production. The program was extended in 2001 and 2002 with an increased budget, and will continue in 2003 until the money is used up. The 0.5-TWh target was reached at the end of 2002.

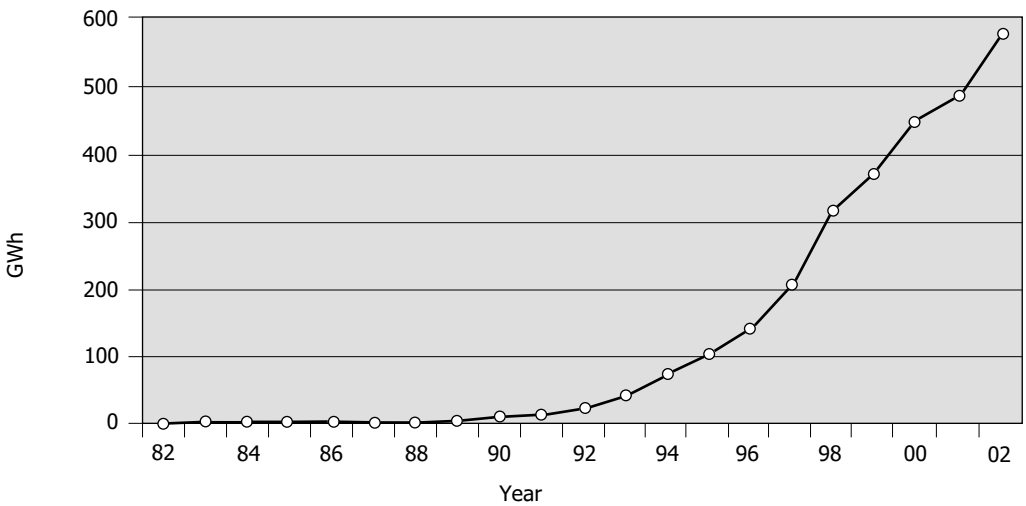

Figure 18.1 Wind-power generation (GWh)

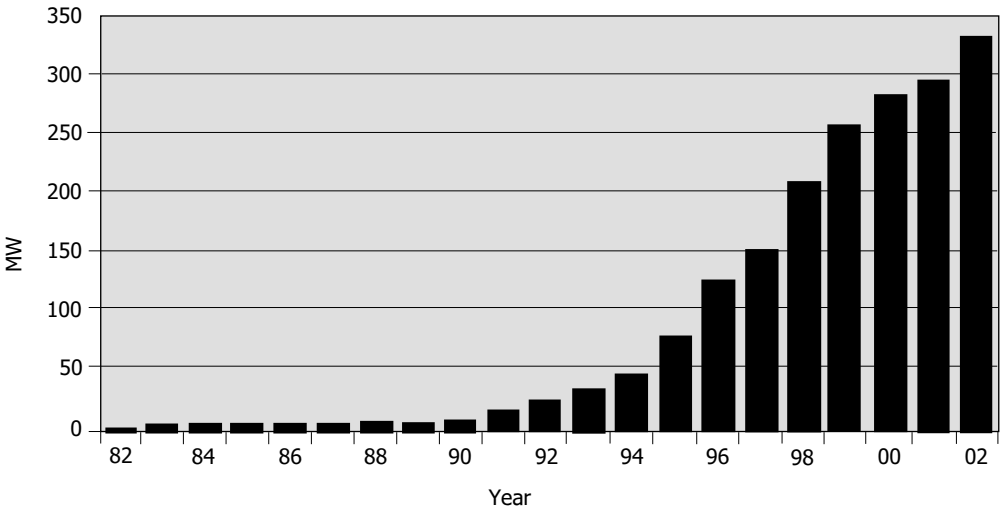

Figure 18.2 Wind-power capacity (MW)

18.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

The expansion of the annual power generation from wind turbines in gigawatt-hours is shown in Figure 18.1. The installed capacity in megawatts at December 31 each year in Sweden is shown in Figure 18.2.

The total installed wind-power capacity in Sweden is 331 MW as of 31 December 2002, an increase of 41 MW, or 14% since 31 December 2001. During 2002, the number of wind turbines increased by 40, or 7%, to 610 turbines. Wind-power generation during 2002 was 565 GWh, an increase of 17% since 2001 (483 GWh). The year 2002 was a nearly normal wind year in Sweden, at 98% of normal. Wind-power generation recalculated to a normal year is 577 GWh.

Rates and Trends in Deployment

No wind turbines in Sweden are erected today without the investment subsidy. Deployment has been more or less evenly distributed over the years, since the investment subsidy budget is evenly distributed. During 2002 the budget was 100.00 MSEK.

Contribution to National Energy Demand

Wind power contributes to the national energy demand with 0.3% of the total electricity production. See Table 18.1 for the total installed electricity capacity and generation in Sweden.

18.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

During the 1990s, the Swedish electricity market was reformed in several steps. Since 1 January 1996, Sweden has had a liberalized electricity market. All consumers are free to choose their electricity supplier. The objectives of the reform have been to increase freedom of choice for electricity consumers and to create conditions for greater pressure on prices and costs in electricity supply.

	2001 (MW)	2001 (TWh)	2002 (MW)	2002 (TWh)
Hydro-power	**16,229**	**77.9**	**16,239**	**66**
Nuclear power	**9 439**	**69.0**	**9,436**	**65.6**
Thermal power production (CHP, cold condensing, GT)	**4 869**	**8.9**	**5,753**	**10.9**
Wind power	**241**	**0.47**	**293**	**0.5**
Net import		**-7.1**		**5.3**
Total	**30,778**	**149.3**	**31,721**	**148.3**

Table 18.1. Total installed electricity capacity (31 December 2001) and generation in Sweden, 2002 (provisional)

The successful deregulation of the Swedish and Nordic electricity markets has led to low electricity prices. There is an obvious risk that renewables might lose market share due to the low electricity prices. This year, however, prices have been higher because of less rain and lower hydro-power generation. The liberalization of the electricity and gas markets forces the wind industry to constantly strive to improve its efficiency and competitiveness.

Since 1 November 1999, wind energy producers compete in the same market as conventional electricity producers. The average North Pool price in Sweden during 2002 was 0.252 SEK/kWh. (See North Pool's homepage, www.nordpool.no, under Elspot and then Monthly Prices.)

On top of that market price, the law grants the wind turbine owner an "environmental bonus," which was 0.181 SEK/kWh in 2002. Additionally, a temporary support of 0.090 SEK/kWh will secure the economy of the "small-scale" electricity producers (maximum generator size 1,500 kW). The wind turbine owner also gets an income from the net owner that is related to the value of the decreased electricity net losses, which on average results in about 0.010 SEK/kWh to 0.015 SEK/kWh. The deregulated market also makes it possible for the turbine owner to sell electricity to any customer. This makes a wind electricity market possible.

A second market stimulation program (15% investment subsidy) started on 1 July 1997. The investment subsidy has a 5.5-year budget totaling 488.00 MSEK. By the end of 2002, the SNEA had received applications for investment subsidies for projects with a total investment value of 4,977.00 MSEK, and the total granted subsidies amounted to 375.00 MSEK. Subsidies granted for 2002 totaled 42.00 MSEK. These projects had a capacity of 48 MW.

Unit Cost Reduction

The mean cost of producing electricity at commercial wind-power plants is 0.38 SEK/kWh (calculated with an interest rate of 6% over a period of 20 years and without state subsidy). In Sweden, support is generally required for wind power to be viable. The larger turbines (1,000 kW to 1,500 kW) erected today are getting cheaper but are still slightly more expensive than the 600-kW turbines.

18.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

The wind turbines erected from 1997 to 2001 in Sweden have a capacity between 225 kW and 3,000 kW. Most are 600-kW turbines (see Figure 18.3) manufactured primarily in Denmark or Germany.

Operational Experience

According to the *Swedish Wind Turbine Monthly* and annual statistics, the average availability during 2001 was 98.2%. During 1996, the figure was 97.8%; during 1997 it was 98.4 %; during 1998 it was 98.5%; during 1999 it was 98.3%; and during 2000 it was 98.8%.

Main Constraints on Market Development

Public attitudes about wind power, especially its impact on the landscape, are important and influence practically every wind project. Noise emission is also important, but perhaps moreso as a "technical" problem. So far, the negative impact on bird life has been minimal, but the question of migrating birds is being raised as more offshore wind-power plants are planned. The issue of marine life in connection with offshore wind power is also much discussed.

Objections from the military have also stopped many wind projects. The military sees risks for disturbances of military microwave links, radar, intelligence activities, and aircraft at low altitudes.

Public Attitudes

A series of investigations into public attitude towards wind-power plants has been carried out. The investigations have included both year-long inhabitants and summer residents around the plants, and politicians and civil servants from the municipalities. Most of those interviewed had positive attitudes towards wind power. In the summer-house areas, there are more doubts about wind-power plants.

Public attitudes are also being investigated in a research project that examines how attitudes can be improved (e.g., by public consultation in the permission process for wind power.)

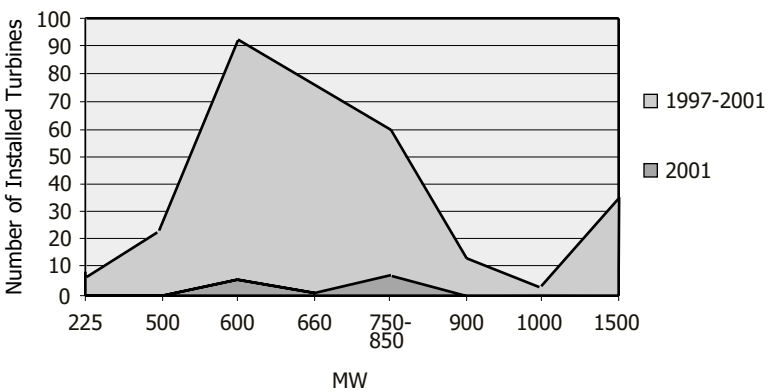

Figure 18.3 Size of installed wind turbines in the investment subsidy program 1997 to 2001. Discrepancies from the 2001 annual report are because 2001 statistics were based on applications, not on turbines actually installed

Noise

Noise is a subject frequently discussed in connection with wind turbine projects. Studies assessing wind turbine noise have shown that not only the sound level and its temporal pattern but also several other factors are important for subjective responses. Work is continuing on how to describe the noise disturbances in physical terms.

Disturbances to Military Structures

A research project is aiming to create a reliable model of the disturbance wind turbines cause for military microwave links, radar, and intelligence activities. Thus far, results show that radar disturbances due to wind turbines have until now been greatly overestimated.

18.6 ECONOMICS

Trends in Investment

During the years 1998 to 2001, approximately 400.00 MSEK per year was invested in erecting wind turbines, since the investment subsidy of 15% has had a budget of 60.00 MSEK per year. An extra 40.00 MSEK per year in 2001 and 2002 increased the investments for those years to 660.00 MSEK.

Trends in Unit Costs of Energy and Buy-Back Prices

Market prices for high-voltage electricity paid by certain customers, industrial plants, and distributors may be close to the bulk power price. On the market for low-voltage electricity, distribution costs are considerably higher, and the price of bulk power as a proportion of the price paid by the end customer is consequently relatively low -- at just under one-third of the price, excluding taxes, payable by a household without electric heating (see Table 18.2). The prices charged to various customer categories are determined by tariff systems, which are made up of a mixture of variable and fixed charges.

During 2002, wind turbine owners received a market tender price and other support as follows.

- A market tender price of approximately 0.240 SEK/kWh, a bit below average Nordpool spot.
- An environmental bonus of 0.181 SEK/kWh.

Typical customer	Network services (öre[1]/kWh)			Electrical energy, (öre/kWh)		
	2001	2002	% Change	2001	2002	% Change
Apartment	42.9	42.8	-0.2	27	35.6	31.8
Single-family house without electric heating	37.5	37.6	0.3	24.2	31.6	30.9
Single-family house with electric heating	20.8	20.9	0.4	22.5	29.6	31.6
Agriculture or forestry	22.2	22.2	-0.1	22.1	29.3	32.6
Small industrial plant	15.3	15.4	0.7	22.1	28.8	30.4
Medium-sized industrial plant				22	28.5	29.7
Electric-intensive industrial plant				21.7	28.3	29.9

[1] **100 öre = SEK 1**

Table 18.2 Price of network service and electricity, excluding taxes, on 1 January 2002 in sales of electricity to various typical customers

• A temporary subsidy of 0.090 SEK/kWh for small generators (maximum 1,500 kW).
• The "local grid value" averaging 0.010 SEK/kWh.

These give a total of 0.521 SEK/kWh.

This price model will be in force until 30 April 2003. Thereafter, a new governmental quota system with green certificates for new renewable electricity generation will probably be implemented.

18.7 INDUSTRY

Two manufacturers have developed large wind turbines in Sweden: Kvaerner Turbin AB and Nordic Windpower AB.

18.8 GOVERNMENT-SPONSORED R,D&D

The overall goal for the Swedish wind energy research program is to develop knowledge within the wind energy area so it will be possible to manufacture and develop wind turbines and utilize wind energy efficiently in the Swedish energy system.

On 1 January 2002, a research and development program in the wind energy area started with a three-year budget of approximately 90.00 MSEK for 2002 to 2004. Research activities are divided into five goal-oriented categories: more confident assessment of power production, cost-effective wind energy converters, effective integration of wind power into the power system, better impact assessments, and appropriate planning and regulation.

The Swedish Defence Research Agency (FOI) manages the program on behalf of the SNEA. More information can be found at www.vindenergi.org.

The program includes basic and applied research as well as development projects. Basic research is fully financed by the SNEA, and applied research requires funding from industry.

Priorities

Research was previously very technology-oriented, but at a time when more wind turbines are put into the landscape, "softer" issues (planning, environmental, acceptance) must be given higher priority. At the same time, it is important to continue research into conventional technologies to increase availability and reduce costs.

New R,D&D Developments

This section presents some current research and demonstration projects.

1. Bird studies at the offshore sites Utgrunden and Yttre Stengrund

A bird study is being performed at the offshore wind-power plants Utgrunden and Yttre Stengrund. Radar has been used to follow bird movement in areas of intense bird migration to evaluate possible effects mainly on eider. The study shows so far that the birds fly at a distance of 200m or more from the nearest wind turbine. Almost no eiders are injured or die at the wind-power site.

2. Wind climate mapping over Sweden and adjacent sea areas

A project that aims at mapping the wind climate in Sweden was started in 2002. The project will produce a database consisting of mean wind, wind distribution, and potential energy production at several levels up to 200 m. The horizontal resolution will be 1 to 1.5 km, and the area covered will be Sweden and adjacent sea areas. The higher-order closure MIUU-model, developed at Uppsala University, will be the primary instrument for mapping the wind climate. A large number of model runs, representative of the climate

conditions, will produce the basic input to a climatological weighting, from which the final database will be the result. Several wind measurements on towers will be used to verify the model output. The large database of modeled meteorological fields (wind, temperature, humidity, and turbulence) may -- apart from being used to estimate the wind potential -- also be used to estimate atmospheric dispersion.

Offshore Siting

1. Nogersund: In 1990, the first offshore-sited wind turbine was erected in Sweden, a 220-kW turbine at Nogersund.

2. Bockstigen, Valar: An offshore demonstration plant with five 500-kW turbines was erected in early 1998 4 km south of Näsudden on Gotland. The Swedish wind farm developer Vindkompaniet AB conducted the project. The Bockstigen Valar project is sponsored by EU (THERMIE) and SNEA.

3. Utgrunden: In autumn 2000, Enron/Tacke erected and commissioned a 10-MW wind farm (seven 1.425-MW turbines) south of the Utgrunden lighthouse in Kalmarsund Sound, between the mainland and the island of Öland. The plant is built 12 km offshore of Bergkvara on the Swedish southeast coast and 9 km from Öland. The Utgrunden project is sponsored by SNEA and now includes a scientific evaluation program with a focus on migrating bird studies.

4. Yttre Stengrund: In spring 2001, the company Vindkompaniet erected and commissioned another 10-MW wind farm (five 2,000-kW turbines, NEG Micon) in Kalmarsund sound, about 4 km from the mainland.

5. Other plans for wind power offshore: In Öresund Sound between Sweden and Denmark, the company Eurowind has received governmental permission for an offshore project with 48 1.5-MW wind turbines. West of the city of Karlskrona in southeast Sweden, the Vattenfall utility has conducted a feasibility study for an offshore project with large, 3-MW to 4-MW wind turbines. In the city's preliminary oversight planning, about 100 large-megawatt wind turbines are planned for the offshore site.

The total number of large offshore wind farm projects in different planning and study phases in Sweden is very large. Discussions are going on with local and regional authorities along several parts of the long Swedish coast – at the West Coast and in the Baltic Sea. The final outcome of these broad activities will depend greatly on the results from the following ongoing governmental initiatives.

- A future Green Certificate system.
- The governmental working group for pilot plants offshore and in the mountains.
- The planning preparations for implementation of wind turbines from the SNEA.
- The government determination of a long-term national deployment target for wind power.

(All of these initiatives are mentioned in the first sections of this chapter.)

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