Chapter 27
Sweden

1.0 Introduction

The new wind energy installations in 2008 had a capacity of 216 MW (Table 1), which is less than the 236 MW that were installed in 2007. However, the installation rate in the two last years has been about four times higher than in previous years. Figure 1 shows the evolution of installed wind power capacity in Sweden from 2003 to 2008. This rate must be increased even more if the new proposed planning goal of 30 TWh/yr can be met by 2020.

2.0 Progress Toward National Objectives

2.1 Swedish energy and electricity mix

The Swedish energy end use in 2007 (numbers for 2007 are used since general statistics for 2008 are not yet available) was 404 TWh. The energy use is divided into industrial energy use 157 TWh; transport 105 TWh; and residential, services, etc. 143 TWh. The total energy supplied was 624 TWh. The difference between energy supply and use consists of losses and use for non-energy purposes. The largest losses were in nuclear power production with 124 TWh. The electricity production was 144.9 TWh in 2007.

Preliminary figures for 2008 indicate a 0.5% increase in electricity production compared to 2007. At the same time, electricity use decreased by nearly 2%, which resulted in net export of electricity from Sweden of about 2 TWh in 2008. The production mix is shown in Figure 2.

2.2 Goals for wind power

In recent political negotiations about energy, the government agreed to suggest a new planning goal for wind power generation of 30 TWh/yr until 2020. The purpose of the planning goal is to create land area for wind in the general public planning (e.g. spatial planning and grid planning) for possible production by 2020. Previously, the Swedish Energy Agency had suggested that planning be divided between 20 TWh onshore and 10 TWh offshore.

With current quotas in the electricity certificate system it is estimated that wind energy will contribute approximately 7 to 8 TWh by 2015. Without a change in quotas in the electricity certificate system, further expansion by 2020 will be marginal. The Swedish Energy Agency, however, notes that increased quotas can work as an effective way to increase the contribution of renewable electricity, and that wind energy likely will contribute to a major increase in renewable electricity production. The Swedish Energy Agency further notes that even though the electricity certificate system likely will work to increase wind energy onshore, nothing will happen in the near future offshore unless additional support is given. The Swedish Energy Agency will therefore look at suggestions for dedicated support for offshore wind.

2.3. Need for changes to the legislation

A change in quotas in the electricity certificate system or other economic support systems will be needed to reach a level substantially larger than 8 TWh by 2020.

Table 1 Key Statistics 2008: Sweden	
Total installed wind generation	1,047 MW
New wind generation installed	216 MW
Total electrical output from wind	1,974 GWh
Wind generation as % of national electric demand	1.4%
Planning Target	30 TWh in 2020 (suggested planning target)

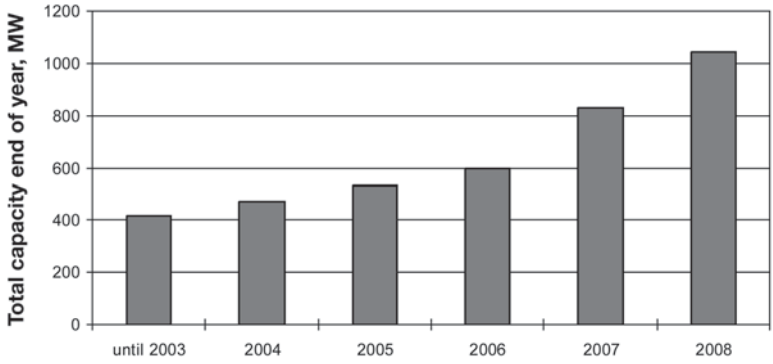

Figure 1 Installed wind power capacity in Sweden 2003 to 2008.

In addition to such changes, there is also a need to make the permit procedure run smoother and a need for changes in the electricity act. Today, several permits are required for a single project according to the Environmental Code, the Planning and Building Act, the Electricity Act, and sometimes other regulations as well. This results in several different reviews with possible multiple appeals, even though it essentially is the same assessment that is made. This results in long wait times from first application until permits are obtained. The government has therefore appointed an inquiry to look over the legislative process and make suggestions for changes. Results from this and other inquiries were recently included in a set of suggestions from the government:

- The Certificate System shall be further developed. For the year 2020, 25 TWh is mentioned as a goal with even further increases thereafter. The Swedish Energy Agency will be given tasks to analyze and develop methods to meet the new goals as well as expanding the market for the Certificate System to other countries
- A new target for wind power of 30 TWh is settled for the year 2020, with 20 TWh onshore and 10 TWh offshore
- The planning process for wind power will be simplified by removing the so-called doubled permissions. In the future, planning should be sufficiently permitted with one of these permissions
- The preconditions for offshore wind power should be investigated in more detail.

Another inquiry into the grid-connection for renewables recently put forward its suggestions for changes to the legislation and procedures coupled to the Electricity Act. The inquiry found that there is a need to solve certain bottlenecks in the electricity network to make it easier to expand the network in an economically sound way (e.g. step-costs occur in the financing for upgrading networks). The inquiry therefore proposes the creation of a grid investment fund to finance investments in the electricity grid for future renewable energy connections. The fund is suggested

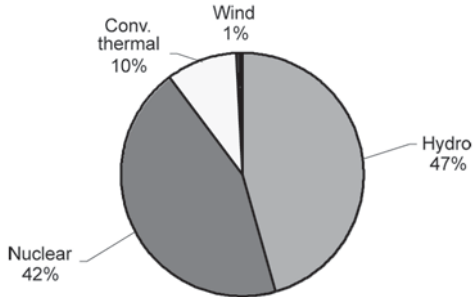

Figure 2 Electricity production mix in Sweden during 2008.

to be financed via network companies and to be shared according to each company's underlying electricity consumption by end customers.

3.0 Benefits to National Economy

3.1 Market characteristics

The consortium Vindpark Vänern is currently constructing a 30-MW park in Lake Vänern. A number of other offshore sites have already obtained permits or are in the permitting process. However, there is no further construction going on since onshore investments are currently more economical.

The expansion onshore is driven partly by the large utilities like Vattenfall and E.ON but also by other actors. Much of project development currently takes place in forested areas with developers continuing to establish land lease contracts with forest owners. The Norwegian power utility Statkraft, for example, has applied for final permitting consent to develop and build 1,140 MW to produce about 2.4 TWh of wind energy. RES Skandinavien together with Hg Capital of the UK are currently building the 95.4-MW wind farm Havsnäs in the northern part of Sweden. The independent developer O2 Vindkompaniet finalized several onshore wind farms during 2008, and a Danish consortium built the 35-MW Bondön project near the city of Piteå.

Apart from the companies mentioned above there are a number of utilities, developers, real estate companies, and private persons developing smaller and larger projects that are still in the planning phase. The current financial crisis will slow the construction of some projects during 2009. Of the erected wind power in 2008, Vestas obtained a market share of 45%, Enercon and Nordex each had a share of 25% and Dynavind (WinWinD) had a share of around 5%.

3.2 Industrial development and operational experience

There are a few manufacturers of small wind turbines in Sweden. The large, international manufacturers of large turbines, Vestas, Enercon, Nordex, and others, have sales offices in Sweden.

On the component side (supply chain), however, the value of manufactured goods is large. The market consists of subcontractors such as SKF (roller bearings and monitoring systems), ABB (electrical components and cable), Vestas Castings (former Guldsmedshytte Bruk AB), Dynavind (tower production), and EWP Windtower Production. Other companies worth mentioning are Oiltech (hydraulic systems and coolers), Nexans (cables), and ESAB (welding equipment). The subcontractors are mainly multinational companies, but smaller entities that find the wind power market relevant to their know-how are also established in Sweden.

World record holder Näsudden II was decommissioned during 2008 (Figure 3). The reason was a major failure of the gearbox. The 3-MW machine began operation on 1 June 1993 and produced 61.4 GWh during 61,469 hours of operation (a world record).

The decommissioning was done by blasting the lower part of the tower, which resulted in collapse of the whole machine. The site will be reused for erection of a 2.5-MW prototype machine from the Indian-German company Kenersys. This project is part of the Market Stimulation Program run by Vattenfall.

3.3 Offshore construction

Three offshore projects, Utgrunden II, Kriegers Flak, and Lillgrund projects have been partly funded with support from the market introduction program as described in Section 4. The Vindpark Vänern project in the largest lake in Sweden is also being built with support from the market introduction program.

For Utgrunden II, all necessary permits are ready and construction was planned to start in 2007. However, the developer E.ON in early 2007 decided to postpone building the wind farm. Having received all tenders for the construction, the financial return did not meet internal minimum

Figure 3 The decommissioning of wind power aggregate Näsudden II.

levels and the project has been put on hold for the time being.

Support for the Kriegers Flak project has been granted for development studies. The project consists of studies of different foundation types, risk assessment for ship safety, and studies of how the wind farm will influence marine currents. The result of the studies will be reported in 2009.

The Lillgrund 110-MW offshore wind farm was put in operation in 2007. The project consists of 48 Siemens 2.3-MW turbines and a main transformer on a separate platform. They are erected on 49 gravity foundations that were built in Poland by a Danish-German Joint Venture, Pihl-Hochtief, and transported on barges to the Lillgrund site. The turbines have a hub height of 68.5 meters and a rotor diameter of 93 meters. Construction of the foundations started in 2006 and was finished during spring 2007. The internal offshore cables within the wind farm and the export cable were laid during summer 2007. The first wind turbine was erected on 3 August 2007. The last turbine was erected in October 2007. The first wind turbine was connected to the grid and started to generate electricity on 4 October 2007. All wind turbines were in operation on 28 November 2007. The availability of Lillgrund in 2008 was 94% and the production was 326 GWh (calculated normal year generation of 330 GWh).

Vindpark Vänern is being built in Lake Vänern, the largest lake in Sweden with a total area of 5,600 km^2. The park is given 40 million SEK (3.7 million €) of financial support from the Swedish Energy Agency, which is 9.5% of the total estimated investment of around 450 million SEK (41.6 million €). The foundations are currently under construction. The water depth on the site is around 5 to 7 meters. The foundations consist of concrete foundations that are secured in the rock by approximately 16 20-meter-long pre-stressed anchors. This makes it possible to have rather small foundations with a minor influence on the lake bottom and the ecosystem.

3.4 Economic Details

The average price of electricity certificates in 2008 was 247.21 SEK/MWh, which is higher than in 2007 when the average certificate price was 195.4 SEK/MWh. Prior to the introduction of the electricity certificate system, Sweden had a subsidy for wind power called the Environmental Bonus. This system is being phased out and will be removed after 2009. During 2008, the value of the Environmental Bonus was 20 SEK/MWh onshore and 130 SEK/MWh. During 2007, the Environmental Bonus was 40 SEK/MWh onshore and 140 SEK/MWh offshore.

Figure 4 shows the average value of the total revenue for wind-generated electricity onshore in Sweden during 2007 (the price paid to a wind turbine owner can be slightly reduced to cover the balancing cost on electricity price for the grid company). The sum is around 56 €/MWh. During 2006 the same number was 76 €/MWh.

4.0 National Incentive Programs

There are three main incentive programs for the promotion of wind power: electricity certificates; production support, the so-called Environmental Bonus; and support for technical development in coordination with market introduction for large-scale plants offshore and in artic areas. The work done in assessing areas of national interest for wind power can also be considered a sort of "soft incentive."

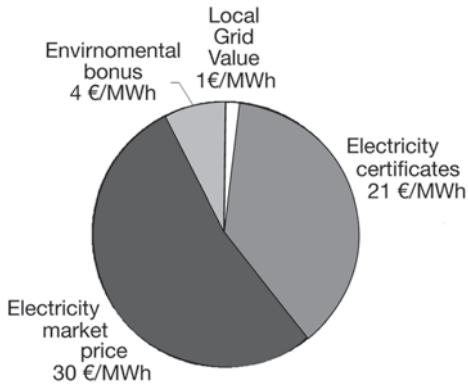

Figure 4 Breakdown of total revenue (56 €/MWh average) for a wind power plant during 2007.

4.1 Electricity certificates

The national production target for renewable energy sources as a result of the EU directive 2001/77, implies an increase in the annual use of renewables in Sweden of 10 TWh from 2002 to 2010. The tool to meet the target is a quota-based system with electricity certificates. The system came into force on 1 May 2003, and is intended to increase the production of renewable electricity in the most cost-efficient way. The increased deployment of renewables, and particularly wind power, will be driven by stipulated quotas that are increased annually, as well as by a quota obligation fee. The system replaces earlier public grants and subsidy systems. The principle is that there should be sellers and purchasers of certificates, and a market to bring them together. There are no specific quotas for wind power. Electricity producers receive from the state a certificate for each MWh of renewable electricity that they produce. This certificate can be sold, to provide additional revenue above the sale of the electricity, improving the economics of electricity production from renewable energy sources and encouraging the construction of new plants for the purpose. The demand for certificates is created by a requirement under the Act that all electricity suppliers and certain electricity users purchase certificates equivalent to a certain proportion of their electricity sales or use, known as their quota obligation. The size of this obligation is increased from year to year, increasing the demand for renewable electricity. The price of certificates is determined by supply and demand, and can vary from one transaction to another.

The current aim of the system is to increase the level of renewable electricity to 17 TWh by 2016 relative to the 2002 level. A new production unit can receive certificates only for a period of 15 years.

Old units therefore leave the system after 15 years. Around 2010 there is a "notch" in the quotas due to the fact that a number of older production units are phased out of the system after 2012. Figure 5 shows the quotas and expected production. The quota-based electricity production in 2007 was about 13.25 TWh (9.6 TWh bioenergy, 2.2 TWh hydropower, and 1.4 TWh wind power). The increase in production from wind and hydro was about equal in 2007 with wind increasing by 0.44 TWh.

4.2 Production support (the Environmental Bonus)

The level of the "Environmental Bonus" is declining for each year until 2009. It will be zero after 2008 for onshore and after 2009 for offshore wind power.

4.3 Support for technical development

In 2003, the Swedish Energy Agency launched a program to support technical development in coordination with market introduction, for large-scale plants offshore and plants in artic areas. The aim is to stimulate the market, achieve cost reduction, and gain knowledge about environmental effects from wind power offshore and in the arctic areas. For the years 2003 to 2007, the budget was 350 million SEK (38 million €). The market introduction has been prolonged another five years with an additional 350 million SEK for the period 2008 to 2012. The projects funded to date are shown in Table 2.

4.4 Areas of national interest

According to the environmental code, land and water areas shall be used for the purposes for which the areas are best suited in view of their nature, the situation, and the existing needs. Priority shall be given to the use that promotes good management from the point of view of public interest. In the environmental code, different areas of Sweden are designated as areas of national interest for different kinds of land use. These are areas of national interest for fishery, mining, nature preservation, outdoor recreation, etc. The idea is to protect specific areas such that the specific national interest not is jeopardized. An area can be of national interest for several kinds of land use. In order to guard the interest of wind energy, 49 geographical areas in

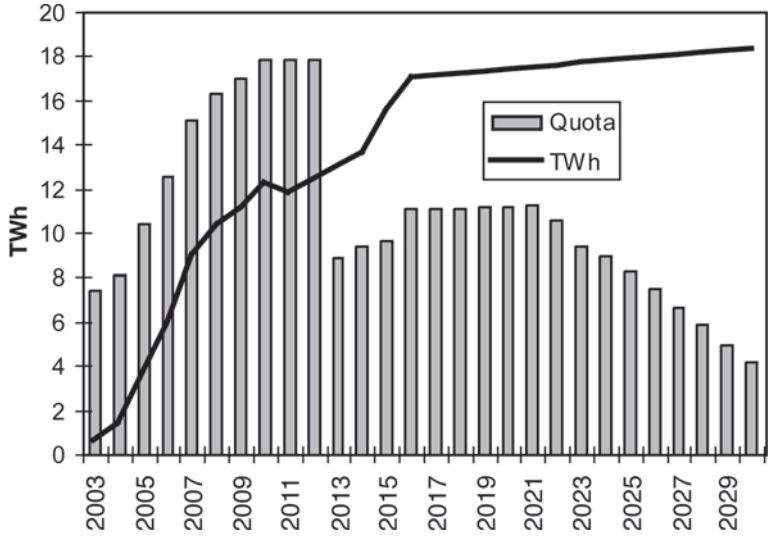

Figure 5 Quotas and production goal of the electricity certificate system. [units on left axis should be TWh]

Table 2 Projects with support from the market introduction program				
Project	Recipient company	Support	Location	Estimated production and estimated year of operation
Lillgrund	Örestads vindkraftpark AB (owned by Vattenfall)	213 MSEK (23 M€)	Offshore	330 GWh; operating since late 2007.
Utgrunden II	E.ON Vind Sverige AB	70 MSEK (7.6 M€)	Offshore	285 GWh; planned for 2008 but recently postponed.
Vindpark Vänern	Vindpark Vänern Kraft AB	40 MSEK (4.3 M€)	Largest Swedish lake	89 GWh; planned for full operation in 2009.
Uljabouoda	Skellefteå Kraft AB	35 MSEK (3.8 M€)	Onshore artic	100 GWh (2008)
Kriegers Flak	Sweden Offshore Wind AB (Vattenfall AB)	9.45 MSEK (1 M€)	Offshore	No production. Only development program.
Vindval		35 MSEK (3.8 M€)		No production. Only research program.

13 counties were pointed out as areas of national interest for electricity production from wind energy in 2004.

The Swedish Energy Agency has started a network to promote the use of wind power. Project financing decisions totaling about 13 million SEK were made in autumn 2008. Most of the projects are designed to strengthen local activities and knowledge of wind power. One project, for example, will develop informational handbooks about regional/local ownership of wind power. Other projects are aimed at stimulating local wind power development, such as support for industry wind power development projects. Projects for strengthening the competence of key people involved in wind power planning and in helping municipalities with contacts between actors related to wind power establishment were also supported. Support was also given to projects that enhance school education and increase the quality of education for wind power technicians.

5.0 R, D&D Activities

Publicly funded wind energy research is mainly carried out within the Vindforsk and Vindval research programs.

5.1 National R, D&D efforts

The Vindforsk II program ran between 2006 and 2008 with a total budget of 45 million SEK. The goal of the program was to generate knowledge in order to facilitate the deployment of wind energy and its integration with the power grid. Vindforsk was focused on research related to the technological development of wind turbines and their interplay with the technical environment in which they operate. Studies have been carried out in the following areas:

- Large amounts of wind power from a market and technical perspective. One study showed that the opportunities for wind power expansion are not limited by its physical potential but will instead largely depend on whether

or not barriers are created by the permitting process, opportunities for grid connection, and technical problems.
• Sound propagation around offshore wind turbines. This was investigated by one project, and the results provided a basis for modification of the Swedish Environmental Protection Agency's model "Sound propagation around offshore wind turbines."
• Wind energy in cold climates. One project focused on development of methods to de-ice or prevent icing on rotor blades, and two projects focused on ice measurement and detection.
• Wind turbine design. Studies were carried out ranging from how wind farms can be optimized with regard to wind turbine wakes, to new splicing methods for steel wind turbine towers.
• Electrical systems in wind turbines. Investigations into the problem of high frequency transients in wind farms have been carried out, amongst others, and are resulting in models for electrical systems with more detailed modeling of circuit breakers in the system.
• Grid connection. Projects have focused on ways during the planning and design stages to ensure that wind farms meet the code requirements of Svenska Kraftnät (the Swedish National Grid) regarding their behavior in the grid.
• Operation and maintenance. Studies have shown that wind turbines have lower availability then previously thought. Review of the statistical data has uncovered errors and misleading information in the reporting system.

A decision for the next stage in Sweden's national R, D&D efforts, Vindforsk III, was made in December 2008. Vindforsk III will run from 2009 to 2012 with a total budget of 20 million SEK/yr. Elforsk, the Swedish Electricity Utilities' R&D company administers the program. The program is financed 50% by the Swedish Energy Agency and 50% by Elforsk. Vindforsk III will be organized in four project packages: the wind resource and establishment, cost effective wind power plant and design, optimal running and maintenance, and wind power in the power system.

The Vindval program is financed by the Swedish Energy Agency and is administrated by the Swedish Environmental Protection Agency. Vindval is a small part of a program called "Market introduction and technology development program" which has run since 2003. Vindval's objective is to facilitate an increase in the expansion of wind power by compiling basic data for environmental impact assessments and permit application processes. Research within Vindval helps compile knowledge about how wind power affects animals, the environment, people, and the landscape. Vindval will also contribute to the increase of competence in and knowledge about the environmental effects of wind power at Swedish universities, colleges, institutes, and companies. Three studies have been finished during the year:

• Environmental optimization of foundations for offshore wind power and studies of small fish at Lillgrund wind farm
• A study about how sea-based fauna is affected by noise from offshore wind power
• Experience from wind power building – support, acceptance, and resistance.

During 2008, the program was extended through 2012 with a new budget of 35 million SEK. Within this time period the program will include new environmental studies in important fields such as social studies; animals in the forests; and effects on economic areas like reindeer farming, nature tourism, and outdoor recreation. Other important areas will be to synthesize and spread information to important actors in the industry about the effects from wind power.

Apart from projects in these programs, other R&D projects are also funded.

• A study on how to decrease disturbances to defense radar systems from offshore wind power have shown that the handling of wind power permitting can be simplified.
• A group at the University of Uppsala is working on direct driven conversion systems for renewable energy. The work is on implementations for wind power, wave power, and power from streaming water. For wind they are working on direct driven vertical axis H-rotors. The generators are built with windings with high voltage cables.

5.2 Collaborative research

Research groups in Sweden participate in all currently operating IEA Wind Research Tasks. During 2008, Sweden re-joined Task 19. Vattenfall AB served as Operating Agent for Task 11, Base Technology Information Exchange in 2008. Participation in the IEA Wind Tasks boosts work in the national programs by allowing the invaluable sharing of expensive data from experiments and measurements.

During late 2007, Sweden also signed a Joint Declaration on Co-operation in the Field of Research on Offshore Wind Energy Deployment with Denmark and Germany. The aim is to co-operate on common research areas and share experience. No firm collaboration projects involving Sweden have started yet. The Kriegers Flak area has projects being planned both on the Swedish and German part of the Flak, and is currently under consideration for the Danish part. It has been identified as a good start for collaboration.

6.0 The Next Term

The two research programs Vindval and Vindforsk will start new research projects in 2009. A lot of the expected growth in wind generation capacity will be in forest areas and also in the northern parts of Sweden in the "low-fjelds." The interest in those regions is prompted by the rather good wind potential as estimated by Swedish wind mapping. Substantial uncertainty, however, exists in the energy capture and loads of turbines in forested areas. The character of wind shear and turbulence is less explored in these areas and projects in the coming research program will be set up to increase the knowledge in this area.

References:

(1) Decommission of Näsudden II, See youtube: http://www.youtube.com/watch?v=Ddr8VwFMJ4I

Author: Maria Danestig, Swedish Energy Agency, Sweden.