Report 2022

Sweden

Illustration of floating vertical-axis wind turbines. *Source: SeaTwirl.*

Authors *Andreas Gustafsson and Pierre-Jean Rigole, Swedish Energy Agency, Sweden.*

In 2022, Sweden installed 2,163 MW of new wind energy capacity, leading to a 20% increase in wind-generated electricity compared to 2021. By the end of the year, the country's total installed capacity was 14,279 MW from 5,164 wind turbines.

In 2022, Sweden installed 2,163 MW of new wind energy capacity (2,042 MW was installed in 2021). By the end of the year, the country's total installed capacity was 14,279 MW from 5,164 wind turbines.

Through the EU Burden-Sharing agreement, Sweden has set a goal to reduce their greenhouse gas emissions by 40% by the year 2030 compared to levels in 2005. On a national level, Sweden aims to reduce their net greenhouse gas emissions to zero by 2045 and thereafter achieve a net zero emissions rate. To achieve this, emissions from activities in Swedish territory must be at least 85% lower than the emissions rate in 1990. A subsequent national goal is to reach 100% renewable electricity production by 2040.

As Sweden's primary wind power RD&D funding agency, the Swedish Energy Agency finances research conducted by universities and industries in several research programmes.

Table 1. Key National Statistics 2022: Sweden

Total (net) installed wind power capacity*	14.2 GW
Total offshore capacity	0.19 GW
New wind power capacity installed	2.2 GW
Decommissioned capacity (in 2022)	N/A
Total electrical energy output from wind	32.5 TWh
Wind-generated electricity as percent of national electricity demand	24.2%
Average national capacity factor**	28.6%
Target	30 TWh
National wind energy RD&D budget	3.84 Million USD

The overarching goals of wind power RD&D are to help Sweden reach its national targets and objectives for a renewable energy system, contribute to business development,and increase jobs and exports.

Highlight(s)

- Wind generated electricity during 2022 increased by 20% compared to 2021.
- Record high average cap of 410 turbines onshore: 5 MW.
- Renewed interest in offshore wind energy in Sweden.
- New collaboration to bring wooden towers to future wind parks.
- New government announcement addressing the abandoning of a previously proposed suppression of grid-connection costs for offshore wind.

Market Development

Targets and Policy

In 2016, the Swedish government, the Moderate Party, the Centre Party, and the Christian Democrats reached an agreement on Sweden's long-term energy policy. However, in 2020 the Moderate party and Christian Democrats left the agreement. Despite this, the goals were ratified by the parliament and are therefore still valid. They consist of a common roadmap for a controlled transition to an entirely renewable electric power system with the following targets:

- By 2030, Sweden's energy will be 50% more efficient than in 2005. The target is expressed in terms of energy relative to GDP.
- By 2040, Sweden aims to achieve 100% renewable electricity production. This target is not a deadline for banning nuclear power, nor does it mean closing nuclear power plants through political decisions.
- By 2045, Sweden will reduce net greenhouse gas emissions into the atmosphere to zero; thereafter, the nation aims to achieve net negative emissions.

These goals alongside abundant opportunities for wind power in Sweden are driving the further development of wind energy in this country.

Since 2003, Sweden has used a technology-neutral, market-based support system to encourage renewable electricity production called the electricity certificate.

In the electricity certificate scheme, the government awards electricity producers a certificate for each MWh produced from renewable resources. These include wind, solar, wave, and geothermal resources, as well as hydropower, biofuel, and peat in combined heat and power (CHP) plants. Of these sources, the main contributors are biopower and wind power. Only new power plants or plants that have undergone recent significant changes are eligible to receive certificates. Producers sell their certificates in an open market to electricity consumers whose demand for electricity certificates is created by a quota which is set in proportion to their total electricity usage. However, energy-intensive industries are exempt from this requirement. The price is determined freely by the market and varies with supply and demand.

Sweden and Norway have shared a common market for electricity certificates since 2012 and trade certificates across borders. The

objective of the common certificates market is to increase the production of renewable electricity by 26.4 TWh by 2020 (compared to 2012). This corresponds to approximately 10% of total electricity production in both countries, achieved primarily through biopower and wind power. In the 2016 Swedish energy policy agreement, the electricity certificate support scheme was extended to 2030 with the goal of producing an additional 18 TWh from renewable sources. **This goal was already achieved in March 2021**. A stop date was introduced so that after the 31st of December 2021, new facilities and plants that become operational after this date will no longer be eligible for electricity certificates.

Progress and Operational Details

In 2022, 410 turbines were commissioned with an average nominal capacity of 5 MW. All of them were onshore [1].

A clear trend is an increase in the size of turbines, as shown in the figures 1 and 2 below. Based on available data from the 410 turbines, the rotor diameter of turbines installed during 2022 were on average 148m, with a nominal power of 5 MW [2].

Contributors Affecting Growth and Work to Remove Barriers

- The government made the decision to reduce connection costs for offshore wind power. To do so, it has assigned the Swedish National Grid (Svenska Kraftnät) to expand the transmission network to areas within Sweden's maritime territory where further opportunities to connect offshore wind are found. Now the government has announced the abandonment of the previously proposed suppression of grid-connection costs for offshore wind in favour of this plan.

- In February 2022, the Swedish Energy Agency, alongside eight other governmental agencies, were commissioned with identifying new areas that should enable an additional 90 TWh of annual electricity production at sea. This task includes formulating impact assessments and starting a dialogue with relevant actors, suggesting areas that may be relevant for electricity production. The results will be presented in March 2023.

- The permit process for wind power and grid infrastructure in Sweden is tedious, often taking around 10 years. The outcome is typically described as unpredictable, especially concerning the so-called 'municipality veto' associated with municipality approval. In the months of May and June 2022, investigators submitted their proposals aimed at streamlining and modernising the permit process. However, as of now, no modifications to the permit process have been implemented.

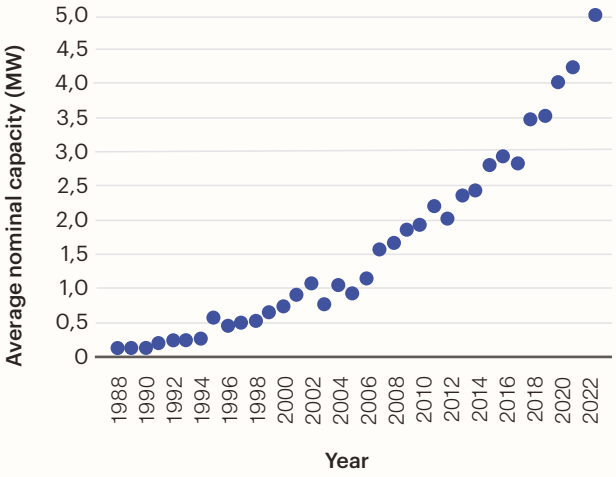

Figure 1. Rotor diameter trend

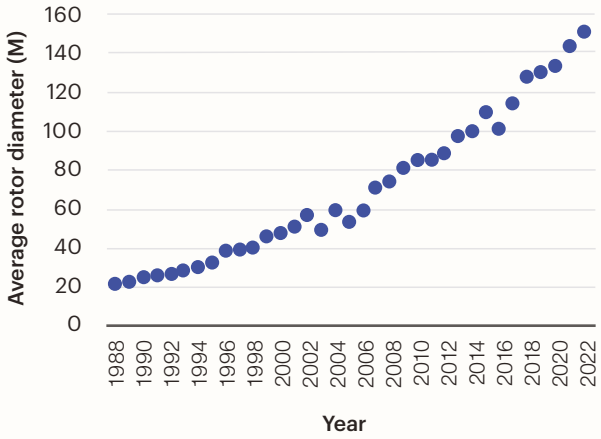

Figure 2. Nominal capacity trend

R,D&D Activities

Four research programmes supported wind energy research during 2022: Future Power System (Framtidens Elsytem), VindEL, Vindval, and Swedish Wind Power Technology Centre (SWPTC). All four programmes were under the supervision of the Swedish Energy Agency.

National R,D&D Priorities and Budget

Vindval [3] is a research programme focused on studying the environmental effects of wind power. The research extends over a period between 2018-2023, with its last call in 2021. The programme is financed by the Swedish Energy Agency and administrated by the Swedish Environmental Protection Agency. The agency has allocated a total of 20 million SEK (1.6 million EUR; 1.8 million USD) for the implementation of the

new phase of Vindval which focuses on wind power and spatial planning.

The VindEL [4] programme runs from 2017 to 2024, with its last call in 2021. It is also financed by the Swedish Energy Agency and has a total budget of 133 million SEK (13 million EUR; 16 million USD). The programme is focused on developing technical solutions within the three priority areas defined in Sweden's strategy for wind power:

- Conflicts of interest and competition for territory usage on both land and at sea.
- Resource-efficient wind power in Swedish conditions with minimised environmental impact.
- Developing new solutions and incentives for a robust electricity grid with high security of supply.

The Swedish Wind Power Technology Centre (SWPTC) [5] is a research centre dedicated to the optimisation of wind turbine design by studying the interaction between turbine components. Their research term spanned from 2019 to 2022 and is collectively financed by industry, universities, and the Swedish Energy Agency, with a total budget of 48 million SEK (4.5 million EUR; 5.1 million USD).

The SWPTC is organised into six theme groups:

- Power and control systems
- Turbine and wind load
- Mechanical power transmission and system optimisation
- Offshore
- Maintenance and reliability
- Cold climates

The Future Power System [6] programme will be conducted from 2022 to 2027 and brings together previous R&D programmes within wind power, hydropower, smart grid, solar power, and ocean energy. With a total budget of 552 million SEK (49 million EUR; 53 million USD), it aims to support a transition to a sustainable energy system by promoting the electrification of other sectors and facilitating an electric power system that is secure, competitive, and embodies ecological and social sustainability.

National Research Initiatives and Results

One Mega Watt floating wind turbine
In November 2022, the Swedish Energy Agency awarded SeaTwirl a grant of 50 million SEK (4.2 million EUR; 4.6 million USD) for the demonstration of its 1 MW floating wind turbine that will be installed in Norway. The project will contribute important data points for the continued growth of the technology. Furthermore, to become an important reference for SeaTwirl's continued commercialisation which is dedicated to developing significantly larger turbines (10 MW and above) in commercial windfarms.

Mapping and digitisation of the flow of wind turbine blades
This project focuses on digitising wind turbine blade streams to develop reuse and recycling solutions. This project is of the utmost importance to enable new and more circular technical solutions that can replace today's non-sustainable method of recycling, i.e., landfill and incineration of redundant wind turbine blades.

Research programme Vindval – Environmental and Social Impact
In 2022, the Swedish Energy Agency granted funding for three projects within Vindval's call "Follow-up of wind power establishments". The purpose of the call is to produce a knowledge base highlighting experiences from recent years' wind power expansion in Sweden.

- Wind power and experience values in nature areas.
- Wind power and unforeseen impacts on wildlife species and their habitats.
- Wind power and bats - evaluation of operational regulation, and wind power in forest environments - mortality of birds and bats.

Vindval published two reports regarding the ecological impacts of wind power in the Baltic Sea (in Swedish) [7], [8].

Collaborative Research

In 2022, Sweden participated in several IEA Wind TCP Tasks:

- Task 11 Base Technology Information Exchange.
- Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power.
- Task 28 Social Acceptance of Wind Energy Project.
- Task 34 Working Together to Resolve Environmental Effects of Wind Energy (WREN).
- Task 39 Quiet Wind.
- Task 42 Lifetime Extension.
- Task 43 Digitalisation
- Task 45 Recycling
- Task 47 Aerodynamic Experiment.
- Task 53 Wind Energy Economics.
- Task 54 Cold Climate Wind Power.

Impact of Wind Energy

The Swedish energy policy aims for long-term social, economic, and ecological sustainability of the energy system while maintaining security of supply. This can be achieved with an active energy policy, incentives, and research funding. Currently, CO2 emissions from electricity production are relatively low because hydropower, nuclear energy, bioenergy, and wind energy are the main contributors to the energy system.

Environmental Impact

Sweden has set a target to achieve carbon neutrality by 2045. In all scenarios, the electrification of industrial and transport sectors is envisioned to be a vital path to reach this target. Given its vast territory with excellent wind conditions, wind power is expected to become the backbone

of electricity production in Sweden, thus playing a key role in meeting this target [9] [10] [11].

Economic Benefits and Industry Development

According to the Swedish Wind Energy association [12], investments in wind power in Sweden (both committed and notified projects) between 2017 and 2024 amount to 117 billion SEK (12 billion EUR; 16 billion USD). The investments contribute to creating a total of 9,156 annual jobs in construction and an additional 14,088 for operation and maintenance. Another economic impact arises from the lower electricity price (minus 0.08 SEK/kWh), that creates a total value for users of 11.6 billion SEK (975 billion EUR; 1 trillion USD).

Next Term

According to the progression of projects initiated and planned, Sweden is on track to reach 50 TWh in total electrical energy output from wind by 2025, representing 26% of the electricity production in Sweden.

Looking to the years ahead, Swedish wind power is expected to focus on offshore operations and joint-production with hydrogen. Specifically, the Baltic Sea offers a manageable proximity to the shore, as well as favourable wind conditions, limited wave height, low water salinity and reduced icing during winter. The area offers a unique combination of challenges and opportunities with the potential to develop bespoke Baltic Sea techniques that will further reduce the cost of offshore operations. Several research programs including Future Power System (Framtidens elsystem), Vindval, VindEl, and the SWPTC are addressing these challenges and opportunities.

References

[1] Swedish Energy Agency, *Vindkraftsstatistik*. Vindkraftsstatistik (energimyndigheten.se)

[2]Swedish Energy Agency, *Vindbrukskollen*. Vindbrukskollen (energimyndigheten.se)

[3] Swedish Environmental Protection Agency, Vindval, Vindval – a research programme (naturvardsverket.se)

[4] Swedish Energy Agency, VindEL, Vindkraft (energimyndigheten.se)

[5] Swedish Wind Power Technical Center, SWPTC - Swedish Wind Power Technology Centre | Chalmers

[6] Swedish Energy Agency, Framtiden elsystem, Framtidens elsystem (energimyndigheten.se)

[7] Swedish Environmental Protection Agency, Vindval, Effekter av havsbaserad vindkraft på marint liv (naturvardsverket.se)

[8] Swedish Environmental Protection Agency, Vindval, Ekologiskt hållbar vindkraft i Östersjön (naturvardsverket.se)

[9] Swedish Energy Agency, Scenarier över Sveriges energisystem 2023, Scenarier över Sveriges energisystem 2023.pdf

[10] Svenska kraftnät, Långsiktig marknadsanalys 2021, langsiktig-marknadsanalys-2021.pdf (svk.se)

[11] Swedish Energy Agency, Utvecklingsvägar för elproduktion 2023, Utvecklingsvägar för elproduktion.pdf

[12] Swedish Wind Energy Association (2022). Över 117 miljarder i vindkraftsinvesteringar 2017-2024 - Svensk Vindenergi