Report 2023

Sweden

World's tallest wooden wind turbine tower. *Photo Credit: Modvion.*

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In 2023, Sweden installed 1,945 MW of new wind energy capacity (2,163 MW installed in 2022). At the end of the year, the country's total installed capacity was 16,224 MW from 5,497 wind turbines.

Through the EU burden-sharing agreement, Sweden aims to reduce greenhouse gas emissions by 40% by 2030 compared to the 2005 level. At the national level, Sweden aims will have zero net emissions of greenhouse gases into the atmosphere by 2045 and should thereafter achieve negative emissions. To achieve zero net emissions, emissions from activities in Swedish territory are to be at least 85% lower than emissions in 1990. Another national goal is to reach 100% fossil-free 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. Wind power RD&D's overarching goals are to help Sweden reach its targets and national objectives for a renewable energy system, contribute to business development, and

Table 1. Key National Statistics 2023: Sweden

Total (net) installed wind power capacity	16.2 GW
Total offshore capacity	0.19 GW
New wind power capacity installed	1.95 GW
Decommissioned capacity (in 2023)	
Total electrical energy output from wind	34.1 TWh
Wind-generated electricity as percent of national electricity demand	25.2%
Average national capacity factor	25.5%
Target	
National wind energy RD&D budget	3.5 million USD

increase jobs and exports.

Highlights

- The Swedish government announced a need to double fossil-free electricity production to 300 TWh by 2045, mainly driven by the electrification of the transport and industry sectors.
- New marine spatial planning areas for energy extractions enable 90 TWh of annual electricity production at the North Sea, the Baltic Sea and the Gulf of Bothnia.
- Roughly 440 TWh of offshore wind power is under development in Swedish waters, of which roughly 190 TWh are applying for permits.
- The world's tallest commercial wooden wind turbine tower, with a height of 105 m, has been installed in Sweden.

Market Development

Targets and Policy

The Swedish Parliament has decided on an overall energy policy goal based on the same three pillars as the energy cooperation in the EU, aiming to unite supply security, competitiveness and ecological sustainability. The energy policy will thus create the conditions for efficient and sustainable energy use and a cost-effective Swedish energy supply with a low negative impact on health, the environment, the climate, and facilitate the transition to an ecologically sustainable society.

In 2016, the 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. In 2023, the goals were amended and voted on by the parliament. The amendment was to change 100% renewable electricity production to 100% fossil-free electricity production by 2040.

The current goals are as follows:

- By 2030, Sweden's energy use should be 50% more efficient than in 2005. The target is expressed in terms of energy relative to GDP.
- By 2040, Sweden should achieve 100% fossil-free electricity production.
- By 2045, Sweden is to have no net emissions of greenhouse gases into the atmosphere; thereafter, the country should achieve negative emissions.

These goals as well as high local wind power potential are driving the development of wind energy in Sweden.

Sweden and Norway jointly operate a technology-neutral, market-based support system for renewable electricity production called the electricity certificate. The objective of the common certificates market was to increase renewable electricity production by 26.4 TWh by 2020 (compared to 2012). This corresponds to approximately 10% of total electricity production in both countries, achieved principally through biopower and wind power.

The 2016 Swedish energy policy agreement extended the electricity certificate support scheme to 2030 with an additional 18 TWh goal. This goal was already achieved in March 2021. The scheme ceased accepting new applications at the end of 2021, which means that new facilities or plants put into operation after the stop date will not be eligible for electricity certificates.

Progress and Operational Details

In 2023, 333 turbines were commissioned with an average nominal capacity of 5.8 MW. All of them were onshore [1].

A clear trend is an increase in the size of turbines, as shown in the figures below. Based on data from 333 turbines, the rotor diameter of installed turbines during 2023 was 159 m on average, with a nominal power of 5.8 MW [2].

Matters Affecting Growth and Work to Remove Barriers

The permit process in Sweden is long (about ten years) and the outcomes have been described as unpredictable, particularly due to the outcome of municipality approval, the so-called "municipality veto".

Work to remove barriers:

- The government appointed a special investigator to analyse how the regulations regarding sea areas for establishing new wind power can be improved and how the permit examination of wind power in Sweden's economic zone can be made more efficient and transparent. The aim is to create a permitting process that provides the conditions for expansion of offshore wind power, while taking other societal interests into account.
- The government appointed a special investigator to review and submit proposals on how the permit process according to the Environmental Code can be simplified and shortened by making the assessment more flexible, efficient and predictable.
- The Swedish Energy Agency and eight other government agencies were commissioned to identify new areas that should enable an additional 90 TWh of annual electricity production at sea. This work includes making impact assessments and establishing a dialogue with key actors about the areas that may be relevant for electricity production.

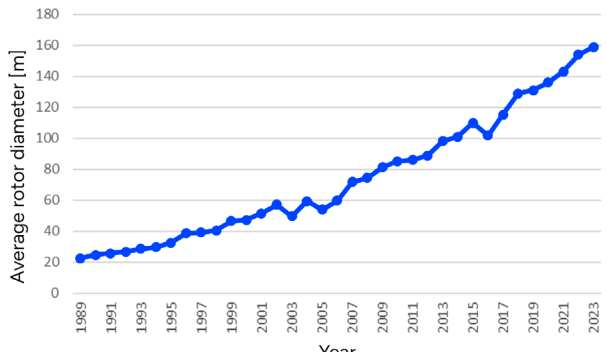

Figure 1. Rotor diameter trend.

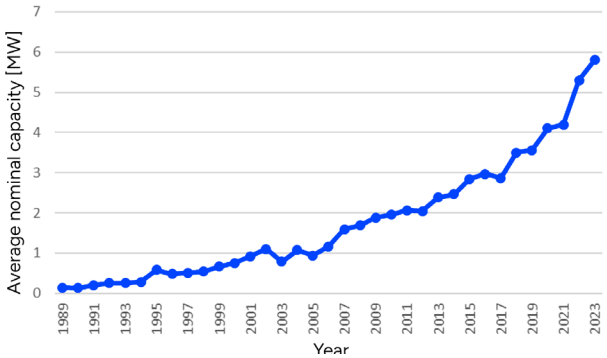

Figure 2. Nominal capacity trend.

RD&D Activities

Four research programmes supported wind energy research during 2023: Future Power System, VindEL, Vindval and Swedish Wind Centre (SWC).

National RD&D Priorities and Budget

Vindval [3] is a research programme focused on studying the environmental effects of wind power. It runs from 2018-2024, 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 SEK 20 million (EUR 1.7 million; USD 1.8 million) for the implementation of the new phase of Vindval, which focuses on wind power and spatial planning.

The programme VindEL [4] runs from 2017-2024, with its last call in 2021. The Swedish Energy Agency finances it and has a total budget of SEK 133 million (EUR 13 million; USD 16 million). The programme focuses on finding technical solutions within three priority areas defined in Sweden's strategy for wind power:

- Conflicts of interest and competition for land use on and at sea.
- Resource-efficient wind power in Swedish conditions with minimised environmental impact.

- Robust electricity grid with high security of supply requires new solutions and incentives.

The Swedish Wind Centre (SWC) [5] is a research hub that conducts research on five research themes about wind power in Nordic conditions:

- Planning of wind power.
- Siting.
- Turbine.
- Operation and Maintenance.
- Electrical System Integration.

Future Power System [6] runs from 2022-2027 with a total budget of SEK 552 million (EUR 49 million; USD 53 million). The programme gathers previous R&D programmes within wind power, hydropower, smart grid, solar power, and ocean energy. The programme supports the transition to a sustainable energy system by facilitating the electrification of other sectors while working for an electric power system characterised by security of supply, competitiveness, and ecological and social sustainability.

National Research Initiatives and Results

World's tallest wooden wind turbine tower.

A world record 105-metre wind turbine tower, made of wood, has been built by the company Modvion. The tower is the company's first commercial installation and was built for the energy company Varberg Energy. As the towers get taller, the logistical challenge increases. Modvion has a patented solution that enables transport on ordinary roads with ordinary trucks. According to the company, the laminated wood tower solution has benefits compared to steel: Wood has a higher specific strength, which enables a lighter construction. High steel towers need extra reinforcement to carry their own weight – which wooden towers do not need.

Grid-forming wind power plant - A coordinated control of wind power and energy storage system to facilitate large penetration of wind power.

The project has developed a coordinated control strategy between the wind power plant and the energy storage system to provide the wind plant with the same grid-forming properties as a conventional synchronous generator. Control strategies for operations under normal and fault conditions were analysed and implemented. New ancillary services for the power system that can be enabled thanks to the control coordination were investigated. A feasibility study of the most suitable energy storage media and the required power electronic interface for the energy storage were carried out. Proper dimensioning of the energy storage system was conducted to reduce the storage requirements compared to today's solutions.

Image 1. Laminated wood tower module. *Photo Credit: Modvion.*

Rekovind2 - Digitisation of wind turbine blade streams for reuse and recycling.

The project focused on digitising wind turbine blade streams for reuse and recycling. This is important to enable new, more circular technical solutions to replace today's non-sustainable recycling, i.e., landfill and incineration of wind turbine blades. The work carried out to map the wind turbine blades in service in Sweden was presented. The digital platform intended to make the re-use of blades reaching end-of-life possible is built around key features that will be required for re-use: a blade database with all the necessary information on the blade (age, damages, material, model, etc.), a map with the blade's geolocation, a digital tool to help blade processing such as cutting, and information on what can be done with EoL blades.

Collaborative Research

In 2023, 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 Projects.
- **Task 34.** Working Together to Resolve Environmental Effects of Wind Energy (WREN).
- **Task 39.** Quiet Wind Turbine Technology.
- **Task 42.** Wind Turbine Lifetime Extension.
- **Task 43.** Wind Energy Digitalisation.
- **Task 45**. Recycling of Wind Turbine Blades.
- **Task 47.** Aerodynamic Experiment
- **Task 53.** Wind Energy Economics
- **Task 54.** Cold Climate wind power.
- **Task 57.** Joint Assessment of Models (JAM).

Impact of Wind Energy

The Swedish energy policy aims for the social, economic, and ecological long-term sustainability of the energy system while maintaining the 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, bioenergy, and wind energy are the main contributors to the energy system.

Environmental Impact

Sweden has the goal to be carbon neutral by 2045. In all the scenarios, the electrification of industry and transport sectors is expected to be the main path. To reach that goal, wind power is expected to become the backbone of electricity production as Sweden is a large country with excellent wind conditions.

Economic Benefits and Industry Development

According to the Swedish Wind Energy Association [7], investments in wind power in Sweden (both committed and notified projects) between 2017-2024 sum up to SEK 117 billion (EUR 12 billion; USD 12.9 billion). The investments create a total of 9,156 annual jobs in construction and 14,088 in operation and maintenance. Another economic impact is a lower electricity price (minus 0.08 SEK/kWh; 0.0069 EUR/kWh; 0.0075 USD/kWh), which creates a total value for users of SEK 11.6 billion (EUR 998 million; USD 1 billion).

Next Term

Based on current planned and in-construction projects, Sweden will reach 55 TWh in total electrical energy output from wind by 2026, which will constitute 28% of the electricity production in Sweden.

In the coming years, much of the focus on wind power in Sweden is expected to turn to off-shore and joint-production with hydrogen. Roughly 440 TWh of offshore wind power is under development in Swedish waters, of which approximately 190 TWh are applying for permits. Much of this deployment will be in the Baltic Sea. With good wind conditions, short distance to shore, limited wave height, low salinity and icing during winter, the Baltic Sea has unique conditions that are both a challenge and an opportunity to develop the Baltic Sea technique that further reduces the cost of offshore. All the research programmes: Future Power System (Framtidens elsystem), Vindval, VindEl and the SWC are addressing these challenges and opportunities.

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År 2023 starkt vindkraftsavslut - Svensk Vindenergi