Report 2022

Finland

Tahkoluoto offshore wind farm during frozen sea conditions *(credit: Suomen Hyötytuuli)***. Maturing wind turbine foundations adapted to Baltic Sea conditions in +15 MW wind turbines will be key to de-risking large-scale offshore deployment in the Baltic Sea.**

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Finland had a record-high wind power installation in 2022: 2.4 GW of new capacity was installed, generating a 74% increase year on year. In connection to the increase in wind power capacity, electricity consumption from wind increased from 9.3% in 2021 to 14.1% in 2022.

Introduction

In Finland, 2022 signified a year where the overall capacity of wind power installations was drastically increased. Within the year, an additional 2,430 MW was installed, which represents a 74% increase in installed capacity compared to the year before. This brings the total Finnish wind capacity to a total of 5,677 MW at the end of 2022 [1].

The consumption of power in Finland in the year of 2022 equated to a total of 82 TWh which constitutes a decrease of 6% compared to the consumption in 2021, with 86.5 TWh representative of pre-pandemic consumption levels. The decline was largely induced by the geopolitical context of the Ukrainian war, which disrupted energy cooperation with Russia since May 2022.

In connection to the increase in wind power capacity, electricity consumption from wind increased from 9.3% in 2021 to 14.1% in 2022 [2]. This allowed wind generated electricity to reach 11.6 TWh, which constitutes a 41% increase compared to the previous year. which constitutes a 41% increase compared to the previous year.

The average capacity factor of wind turbines increased to 33.2% in 2022, compared to 31.9% the year before. Meanwhile, the wind conditions remain similar between these periods, suggesting that newer, taller turbines are driving the increased efficiency of the capacity factor.

In an effort to adapt to higher prices, industry and households have reduced their electricity consumption. To compensate for the decline in net electricity import, which equated a decrease in 5 TWh and lower production from natural gas (-3 TWh), the following power plants have increased their production. Wind by an additional 3 TWh, nuclear added 2 TWh and coal by 1 TWh [2].

Highlights

- Record high installation: 2.4 GW of new capacity was installed, generating a 74% increase year on year.
- CO2-neutral electricity increased to make up 89% of electricity production (This includes wind, solar, nuclear, hydropower and biomass).
- An 8 TWh decline in electricity import was partly compensated for with an additional 3 TWh of wind capacity following the beginning of the war in Ukraine and reduced production in natural gas power plants.

Market Development

Targets and Policy

- Finland's climate policy is primarily enacted by the national Climate Act, which as of the 1st of July 2022, has put a range of new targets into action. The Climate Act aims to reduce carbon emissions by 60% by the year 2030, 80% by 2040, and 90% by 2050, however with an aspirational target of 95% by 2050. These reductions are all relative to the emissions levels of 1990. Furthermore, the new Act stands by its objective to reach carbon neutrality by 2035 [3].
- The 2022 government policies relating to the climate and energy strategy provide support for demonstration projects regarding new renewable energy projects [4]. The approximate annual budget for this purpose is 150 million EUR (168 million USD) [5].
- The national climate and energy strategy envisions a scenario where wind energy is able to provide 24% of electricity consumption in 2023, which is equal to 23 TWh out of a total of 95 TWh. By 2035, they aim to increase this proportion of wind energy provision to 30 TWh out of 104 TWh [5].

Table 1. Key National Statistics 2022: Finland

Total (net) installed wind power capacity*	5.678 GW
Total offshore capacity	0.073 GW
New wind power capacity installed	2.430 GW
Decommissioned capacity (in 2022)	0.009 GW
Total electrical energy output from wind	11.56 TWh
Wind-generated electricity as percent of national electricity demand	14.1%
Average national capacity factor**	33.2%
Target	N/A
National wind energy R&D budget	N/A

- In relation to an existing target, which expects 51% of Finland's gross final energy consumption in 2030 to derive from renewable energy sources (RES), the expected share of electricity consumption from renewables (RES-E) will increase to 60% in the same year [5].

- In coordination with its Baltic Sea-facing neighbour states, the residing Finnish government of 2022 declared their ambitions for a large-scale deployment of offshore wind in the Baltic Sea region [6]. The Finnish government anticipates that market conditions will dictate the progression of the project and will therefore not require extensive grant aid. Nevertheless, it acknowledges the requirement for technical solutions, such as offshore foundations adapted to sea ice conditions [5]. According to the national climate and energy strategy, the implementation of at least one offshore wind demonstration project is planned to primarily be supported through EU funding, while the regulation, administrative processes and fees related to the utilisation of the area for an offshore wind energy project will be developed [5].

Progress and Operational Details

- The Nordex-Acciona N163 machines installed in Karhunevankangas are a typical example of wind turbines installed in Finland. The turbines feature a 5.7MW power rating, span 163 m in diameter and have a hub height of 159 m. The average of newly installed turbines in Finland now have on average a diameter of 159 m and 146 m hub height [1].

- In 2022, the average capacity factor was 33.2%, which is comparable to the average of the period between 2018 and 2022, namely 32.9%. Similarly, the 2022 wind power index remained closely aligned with the long-term average of 1.00, as shown in Figure 1 [7].

- The offshore wind project pipeline in Finland has 13 GW (11/2022) in different stages, with 1.3 GW having completed the environmental impact assessment [14].

- The development of offshore wind will be partially driven by an auction model which leases public areas governed by Metsähallitus, the state-owned agency responsible for forests and marine areas. The first project will be the Korsnäs 1.3 GW wind farm, developed in

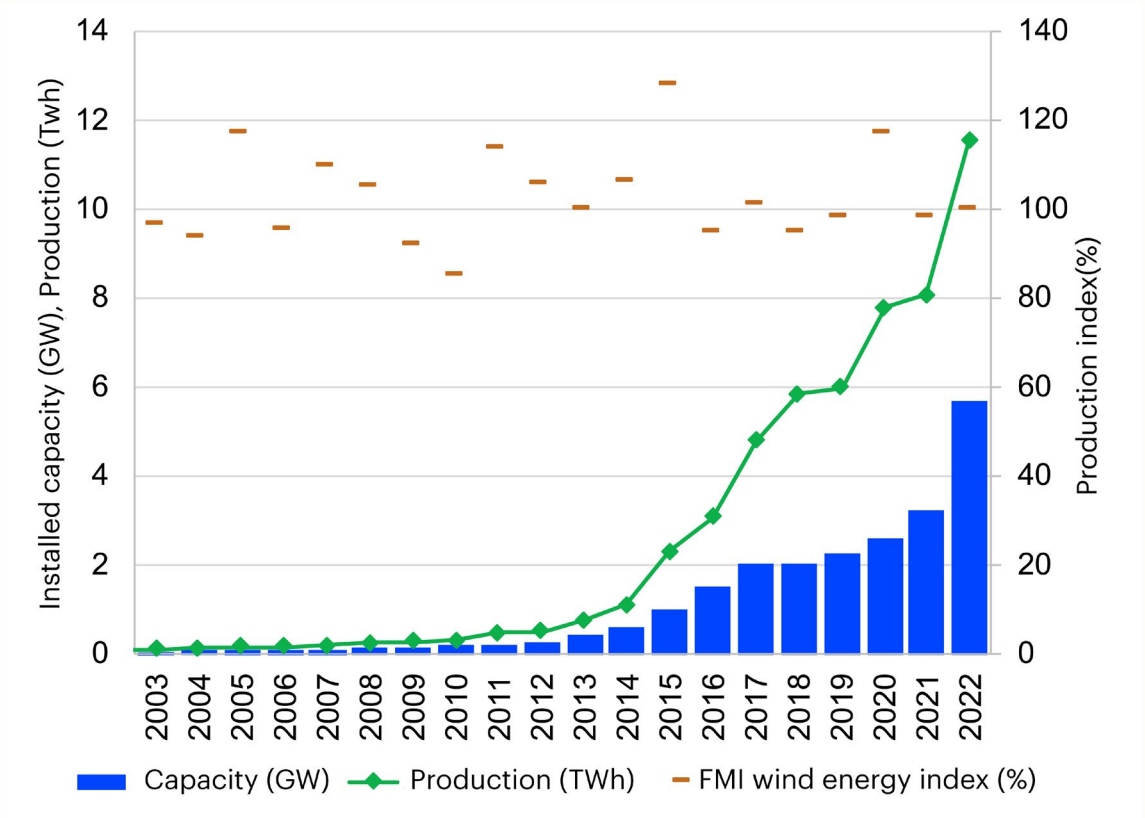


Figure 1. Development of wind power capacity and production in Finland. The wind power index gives the yearly generation compared to the long-term average (100%) provided by the Finnish Meteorological Institute (FMI).

collaboration with Vattenfall [8]. Furthermore, Finland intends to launch five tenders generating more than 6 GW of offshore wind capacity. The additional two tenders per year will be launched in 2023 and 2024 [9].

- As early as January 2022, the government granted permits to WPD, now known as Skyborn, and OX2, to explore offshore wind projects the areas west of Jakobstad and Hailuoto in Finland's exclusive economic zone [10]. Additional permits were granted later during the year.

Matters Affecting Growth and Work to Remove Barriers

Interference with radar surveillance has prevented the deployment of wind power in eastern Finland. According to a governmental report produced in 2023, potential solutions may include a combination of active and passive sensor systems, including airborne surveillance equipment. It furthermore recommends taking a phased approach, focusing on one area at a time. Notably, it is challenged by the estimated lifecycle cost of these solutions, which appears to be significantly higher than the resources and obligations of the defence forces [11, 12].

In addition, the current clustering of onshore wind capacity in western Finland may pose a challenge to its future transmission capacity. To address this, the national climate and energy strategy intends to examine the principles of connecting wind power to the network, while enabling the cost-effective use of the network and fair distribution of costs between network users [5]. The transmission system operator, Fingrid, is prepared for a dramatic increase in both onshore and offshore wind power, alongside strong transmission demands from north to south and west to east, among other scenarios.

Fingrid is additionally preparing to run a pilot project in 2023, which addresses the practical implications related to the inclusion of wind power in the reserve market. The goal is to promote wind power in the market for automatic reserve products, and ultimately to ensure that the power balance can be managed effectively in the future [13].

The electricity spot price experienced a significant surge to 154 EUR/MWh (173 USD/MWh), which constitutes a fourfold increase compared to the average of the preceding 10 years. Meanwhile, the market value of wind power stands at 110 EUR/MWh (123 USD/MWh), which accounts for 71% of the average electricity spot price. In 2023, electricity spot prices have begun to decline and are expected to remain at lower levels compared to 2022.

Further construction of wind power will be promoted by allocating additional funding towards national surveys researching wind power, as well as for planning, licensing, and establishing related studies guiding wind power construction in municipalities and regional councils. A total of 1.5 million EUR (1.7 million USD) in additional funding was allocated towards the 2022 budget [5].

In addition, the large-scale deployment of offshore wind in the Baltic Sea is dependent on the performance demonstration of offshore foundations. Notably, an area which still requires attention are areas affected by seasonal sea ice.

To facilitate a mutual understanding and coordination between the sectors of reindeer husbandry and the wind power sector in Finland, an operating model has been created. This model takes each phase of the lifecycle of a wind power project into account and offers concrete examples of best practices which consider the implications affecting reindeer husbandry at each stage [15].

To conclude, the popularity of wind power in Finland remains high. According to an energy attitude survey, 82% of Finns support the further development of wind power [16].

RD&D Activities

National RD&D Priorities and Budget

- The Finnish Funding Agency for Technology and Innovation, Business Finland (BF), continues to fund research and innovation in the country. Wind power is aligned with the key aspects of sustainability and economic growth, which define the Business Finland strategy for 2025.

- Government ambition in wind R&D includes offshore wind demonstration in the Baltic Sea, where the effect of seasonal ice cover needs to be fully understood. In coordination with this goal, the implementation of at least one offshore wind demonstration project will be supported. In this context Suomen Hyötytuuli has received 30 million EUR (33 million USD) in funding for Tahkoluoto offshore wind power demonstration project. The project entails the installation of two 15 MW offshore wind turbines near the Tahkoluoto offshore wind farm. This will be the very first offshore wind farm in frozen sea conditions.

- Public R&D funding from BF for wind power has averaged 1.5 million EUR (1.7 million USD) annually during the past decade, see Figure 2.

National Research Initiatives and Results

- Business Finland's project TUTTE (Wind power production and efficiency 2020-2022) is an initiative aimed at understanding the factors contributing to, as well as limiting the energy production of wind farms in the Finnish climate. It focused on wind farm efficiency, wakes, and the implications of the surrounding terrain,

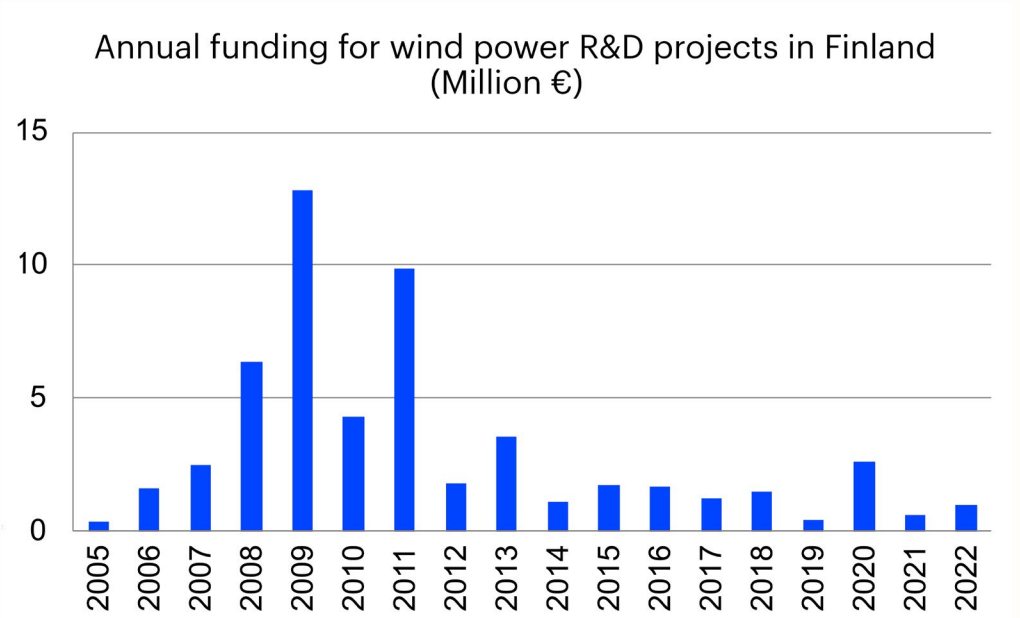


Figure 2. Public R&D funding in Finland has averaged 1.5 million EUR (1.7 million USD) annually during the past decade *(source: Business Finland* [17]*)*.

including atmospheric icing. A measurement campaign was performed in two wind farms producing a research dataset including nacelle LIDARs and SCADA in these farms. The dataset, which was collected over the course of a year, showed that a given wind turbine will be operating with clean inflow between 31–65% of its operation, 20–26% of the time it is affected by a single wake, and the remainder of the time affected by two or more wakes [18]. Additionally, the study finds the presence of two wakes resulted in a decrease in efficiency of 5–9%. One of the sites, a representative Finnish site located onshore in the South Ostrobothnia region, is found to have an average of roughly 250 hours of meteorological icing per year (equivalent to 2.9% of a year), led to annual production losses of 3–4%, see Figure 3. The study furthermore suggests that most icing occurs at temperatures close to 0°C and at wind speeds below 7 m/s.

- A further development of icing forecasts is carried out by FMI in the project "Icing of critical infrastructure" which is funded by the National Emergency Supply Agency.
- FMI furthermore takes part in the WindySea project which is led by Aalto University and funded by the Academy of Finland. The role of FMI is to enhance the knowledge surrounding future scenarios regarding icing conditions, with a dedicated focus on offshore wind parks.
- Project HOPE (Highly Optimised Energy Systems) produced a wind power forecasting system providing an estimated aggregated power production, which was developed by the Finnish Meteorological Institute (FMI). The system is planned to be deployed in Spring 2023 on the FMI web page.
- On the basis of work funded by Business Finland and Wihuri Foundation, VTT produced results on the role of offshore wind, offshore electrolysis and how successfully large share wind might take in different climate zones (https://doi.org/10.1016/j.apenergy.2023.121093).

Test Facilities and Demonstration Projects

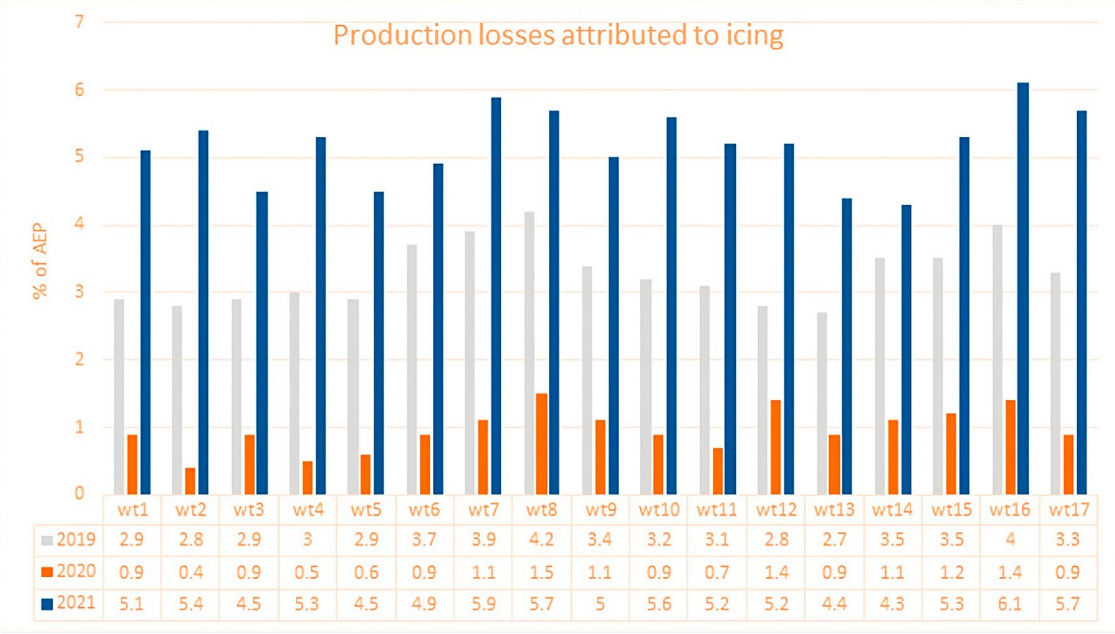
- The KiMuRa project (recycled crushed raw material) tested a solution for recycling blade material of wind turbines, utilising composite in cement production [19].

Collaborative Research

Finnish research organisations and industry are active in several EU, Nordic, and IEA research project frameworks.

FMI collaborates with the Royal Netherlands Meteorological Institute (KNMI) and the Royal Meteorological Institute of Belgium (RMI) on high-resolution impact modelling for Belgium Offshore Platform (BOP). The collaboration is part of Work Package 8 of the Destination Earth project on weather extremes.

VTT participates in the HEU project AIRE (2022-2025), which is aimed at understanding wind farm wake interaction and blade erosion, with a focus on model validation and mitigation strategies through wind turbine control.



	wt1	wt2	wt3	wt4	wt5	wt6	wt7	wt8	wt9	wt10	wt11	wt12	wt13	wt14	wt15	wt16	wt17
2019	2.9	2.8	2.9	3	2.9	3.7	3.9	4.2	3.4	3.2	3.1	2.8	2.7	3.5	3.5	4	3.3
2020	0.9	0.4	0.9	0.5	0.6	0.9	1.1	1.5	1.1	0.9	0.7	1.4	0.9	1.1	1.2	1.4	0.9
2021	5.1	5.4	4.5	5.3	4.5	4.9	5.9	5.7	5	5.6	5.2	5.2	4.4	4.3	5.3	6.1	5.7

Figure 3. Production losses attributed to icing in the wind turbines of a representative wind farm in South Ostrobothnia (Finland) during 2019-2021. Values as percentages of annual energy production [18].

Within the IEA Wind TCP, Finland participates in the following Tasks:

- Task 11 Base Technology Information Exchange, which produces valuable information in identifying issues important for wind R&D in Finland.
- Task 25 Design and Operation of Energy Systems with Large Amounts of Variable Power Generation (Finnish organisations VTT and Recognis serve as co-operating agents).
- Task 44 Farm flow control: VTT additionally acts as a participant in this Task.
- Task 46 Erosion of wind turbine blades: Finland serves as a co-operating agent in this Task which was approved in 2020.
- Task 51 Forecasting for Wind Energy: Vaisala is the lead provider of weather instrumentation which aids the Finnish Meteorological Institute in conducting research related to wind forecasting, such as the Business Finland project, HOPE. Furthermore, it is responsible for operational numerical weather prediction and model development initiative, as part of their joint international efforts known as MetCoOp.
- Task 54 Cold Climate wind power (Operating agent VTT): Finland has a national interest in addressing the challenges of adapting wind energy to cold climates. This Task has been instrumental in the deployment of wind energy in harsh environments, such as the climates in Finland.

Impact of Wind Energy

Environmental Impact

Since 2012, renewable energy sources such as wind, hydro, wood, among others, increased gradually from producing 31% of total energy consumption to 42%. Wind has been a significant contributor, which is highlighted by its growth from 0.1% to 3.2% of total energy consumption. Although it presents an upward trend, wind energy still contributes less than wood and hydro power. Meanwhile, the production share of fossil fuels, including peat, gradually decreased from 50% to 34% of total energy consumption [20].

Economic Benefits and Industry Development

- Wind energy projects completed in 2022 provided 2.9 billion EUR (3.3 billion USD) in investment to Finland. Hereby, wind has emerged as a significant driver of foreign investment in the country [1].
- A typical Finnish wind farm consisting of 20 turbines is estimated to generate through its lifecycle, a total turnover of 911 million EUR (1 billion USD). This includes a value-added amounting to 636 million EUR (714 million USD) and approximately 213 million EUR (239 million USD) in investment. The expected demand for local labour is 1,878 person-years, and is projected to generate a tax revenue of 264 million EUR (296 million USD). Additionally, the contribution to gross domestic product is 654 million EUR (734 million USD) [21].
- In 2022, wind and solar power plants generated a total of 23 million EUR (26 million USD) of real

estate tax. In small municipalities, the real estate tax generated by the power plants has become a significant source of income [22].

Next Term

After an exceptional year in 2022, onshore wind deployment is expected to stabilise. Year-on-year installations are furthermore expected to consolidate around 1 GW per year [1].

Meanwhile, large-scale offshore wind continues to advance, led by the Korsnäs 1.3 GW development alongside the additional Metsähallitus leases announced from 2023 onwards totalling 6 GW.

Floating offshore wind projects will furthermore continue to be studied [23].

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