Finland

Table 1. Key Statistics 2017, Finland	
Total (net) installed wind power capacity	2.0 GW
Total offshore capacity	0.07 GW
New wind power capacity installed	0.516 GW
Decommissioned capacity (in 2017)	0.003 GW
Total electrical energy output from wind	4.8 TWh
Wind-generated electricity as percent of national electricity demand	5.6%
Average national capacity factor	32.5%
Target	No target

OVERVIEW

In 2017, Finland consumed 85.5 TWh of electricity with a peak demand of 14.3 GW. Carbon emissions from power generation in Finland totaled only 89 g CO_2/kWh—the lowest ever measured.

Wind power production broke the previous records and has now become the norm. At the end of 2017, installed wind power capacity amounted to 2,044 MW with 4.8 TWh of production. Renewables provided about 35.5% of the country's electricity consumption in 2017: 17.1% from hydropower, 12.8% from biomass, and 5.6% from wind power.

The National Energy and Climate Strategy for 2030 (published in 2016) introduced a tendering-based subsidy scheme, which fulfilled the new European Union (EU) guidelines for technology neutrality, was in preparation in 2017. Finland is aiming for 1.4 TWh of production capacity to be put out to tender between 2018-2020.

The 42-MW offshore demonstration wind farm, designed for and constructed in the demanding sea ice environment on the Finnish west coast, began operation in August.

MARKET DEVELOPMENT

National Targets & Policies Supporting Development

As part of the EU's 20% target, Finland's renewable energy source (RES) goal is 38% of the final energy consumption in 2020. The estimated share of RES in 2017 was 39%, exceeding the goal for 2020. The 2008 Climate and Energy Strategy set a wind power goal of 6 TWh/yr for the year 2020 (6-7% of the total electricity consumption).

Finland implemented a market-based feed-in system with guaranteed pricing, managed by the Energy Authority, in 2011. The guaranteed price for wind power was set at 83.50 EUR/MWh (100.2 USD/ MWh) for 12 years. Producers are paid the guaranteed price, minus the three-month average spot price, as a premium every three months.

In 2016, the Finnish government published the National Energy and Climate Strategy for 2030 with the goal for 50% renewables in the energy end use. The government is currently planning a technology-neutral tendering process to acquire renewable-based generation, which is expected to launch in late 2018 [1].

The Ministry of Economic Affairs and Employment can also grant energy aid, which is increasingly targeted to new technology projects [2].

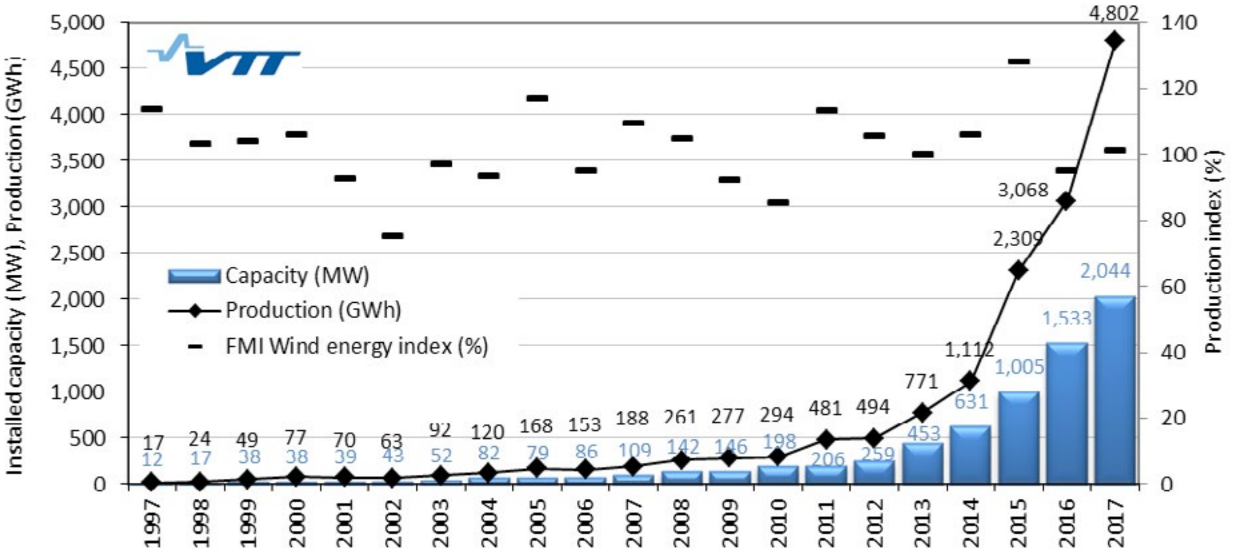
Progress & Operational Details

The feed-in tariff (FIT) system closed for new wind farms on 1 November 2017. The last wind farm was approved at the FIT system on 4 January 2018.The FIT-based system led to a market of 516 MW in 2017 (153 turbines). Three turbines with a total capacity of 3.4 MW were dismantled. The wind power capacity in operation reached 2044 MW.

Development toward larger turbines continued throughout 2017. The average turbine rating is now 2.9 MW for all turbines installed and 3.3 MW for the new turbines installed during the year. The largest single wind farm in operation has 34 turbines with 3.45 MW each and a total rated power of 117 MW, with expected annual energy output over 0.4 TWh/a.

Finland's total offshore capacity is 86.5 MW, including 44.3 MW built on caissons and 28.4 MW on small artificial islands.

Figure 1. Development of wind power capacity and production in Finland. Production index gives the yearly generation compared to long term average (100%), based on Finnish Meteorological Institute (FMI)



The 42-MW offshore demonstration wind farm in Pori on the Finnish west coast started operation in August 2017. Following a rush to secure sites for larger offshore wind power plants, interest to build has been low due to the improved economy of land-based turbines and lack of incentives offshore.

Wind-generated electricity increased by 55% in 2017 (from 3.1 TWh to 4.8 TWh)—80% of Finland's goal for 2020 and 5.6 % of the country's annual gross electricity consumption (Table 1, Figure 1). The weighted average capacity factor of wind farms operating throughout the year was about 32.5% (an increase from 27% in 2016). The production index for wind power averaged in 101% in 2017 (compared to 95% in 2016). Turbines in forested areas have high towers and larger rotors, and these designs provide considerably higher capacity factors than earlier turbine designs (Figure 2).

The average spot price in the electricity market Nordpool was 33 EUR/MWh (40 USD/MWh). This price is low, but it is a slight increase from the 32 EUR/MWh (38 USD/MWh) price in 2016.

Matters Affecting Growth & Work to Remove Barriers

Finland's main challenge in the future will be keeping the market going between the current renewables support system and the coming tender-based system, which was still in the planning stages. All developing projects are anxiously waiting for information regarding the next auction system.

The impact of wind farms on radar systems is preventing some projects in Finland, especially in the Southeast, Eastern and Northern parts of the country. The grid capacity is limiting new project development in some areas, where the project pipeline is large due to good wind conditions.

A government-financed study of the health and environmental effects of wind power was published in May 2017. The effects of low-frequency noise and infrasound on health are no longer a major issue in public debate, partly due to the results of the study. The government issued a decree on noise limits in 2015, following 2012 noise limit regulations and 2014 guidelines on modeling and measuring the wind turbine noise.

Public acceptance of wind power remains high. According to annual survey on energy attitudes, 75% of Finns support increasing wind production capacity.

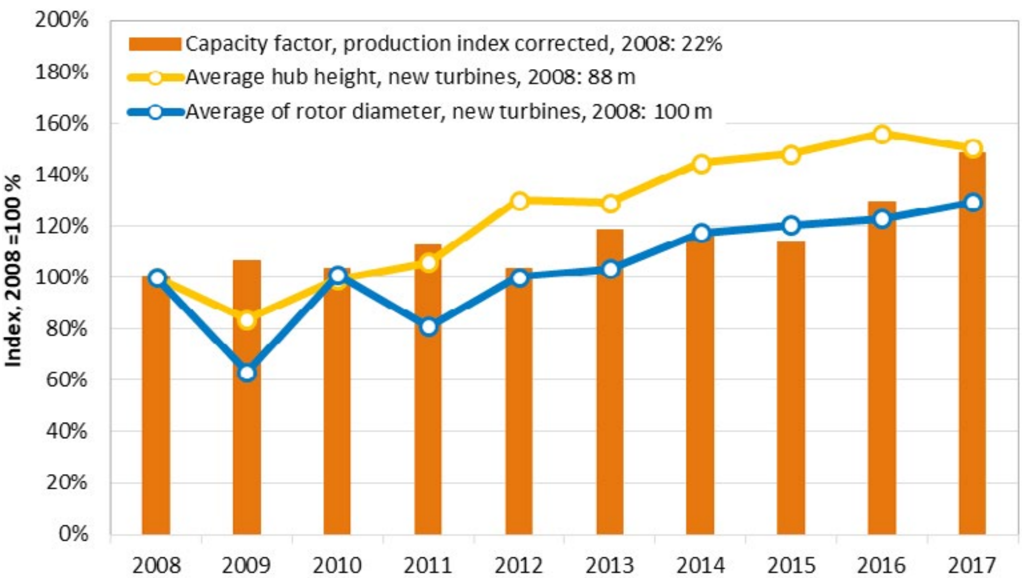


Figure 2. Growth of turbines built in each year and development of average capacity factor of all wind turbines in Finland, 2008-2017

National R,D&D Priorities & Budget

The Finnish Funding Agency for Technology and Innovation (Tekes) became BusinessFinland in January 2018, which is the main public funding organization for research, development, and innovation in the country, promoting competitiveness and international growth for Finnish companies. The focus is on assisting SMEs and supporting market-transforming solutions by large companies. BusinessFinland focuses on eight themes, and wind R&D projects fit into the following:

- Arctic: business activities from winter seafaring to digital services
- Digitalization: creating a competitive advantage as a global innovation and technology leader

Since 1999, Finland has not had a national research program for wind energy. Instead, Tekes/BusinessFinland funds individual industry-driven projects. The public funding level for wind power R&D projects in 2017 was around 1.2 million EUR (1.4 million USD) (Figure 3). Ongoing wind power-related R&D projects are mostly industrial development projects.

National Research Initiatives & Results

The Finnish Wind Power Research Network (FinWindResearch) is an ecosystem of wind power experts established in 2016 for information exchange, cooperation, and new innovations. FinWindResearch currently operates on a voluntary basis and consists of more than 30 members from over ten Finnish research institutes. As a catalyst for new innovations, FinWindResearch organizes a yearly seminar for all Finnish wind power experts to network, exchange information, and share and distribute latest research results via the FinWindResearch website. The network plans to host other events, such as web-based workshops, in the future.

The Health effects of sound produced by wind turbines project launched as a prerequisite to include wind power in the new auction-based premium tariff for renewables. The project concluded that there is a difference in the prevalence of annoyance between wind power areas, and that factors other than sound pressure level are associated with annoyance [3]. The effects of infrasound were studied, too, as some people who reside close to wind turbines have symptoms that they associate with infrasound from wind turbines. The report justified the need for additional research, as scientific studies on the effects of exposure to infrasound and audible noise from wind turbines are limited.

The Wind Turbine Sound Modeling and Measurement (windsome.uwasa.fi) project uses in-the-field observations of acoustics and wind turbine sound modeling methods in combination with a real-time subjective feedback system and background questionnaire. This unique combination of long-term sound measurements and real time subjective feedback is new; with the knowledge gained, it should be possible to model the wind turbine acoustics in different weather conditions and identify problematic conditions.

The EL-TRAN Consortium works to rethink the totality of the electric energy system under the energy transition. EL-TRAN published an updated potential assessment for wind power in Finland. It showed that the new low-specific rating turbines with high hub heights provide considerably higher technical potential: 100% of Finland's electricity demand can be met with wind power using best sites only (>47% capacity factor), compared to >40% capacity factor for 2002-2004 vintage turbines. New technology also reduces the uncertainty of land use restrictions. This assessment, including economic potential, will be published in *Nature Energy* in 2018.

The Neocarbon energy national project created visionary global 100% renewable energy scenarios (http://www.neocarbonenergy.fi/library/reports/). Wind energy has a strong role in the Northern hemisphere, but future cost reductions of solar PV, together with electric batteries, could mean that relatively little wind will be used in the solar belt.

Test Facilities & Demonstration Projects

VTT has operated an Icing Wind Tunnel facility for more than ten years. In 2017, VTT coordinated an industry consortium project to increase ice detector reliability and substantially reduce the time-to-market of new ice detector products. The project goal was to shift from the current slow, outdoor, full-scale "winter season" ice detectors testing to an accelerated, controlled, and repeatable laboratory "five winters in one week" testing at the VTT Icing Wind Tunnel (see Youtube video here) [4]. The novelty content of this project was high, and the results will benefit both industry and research community [5].

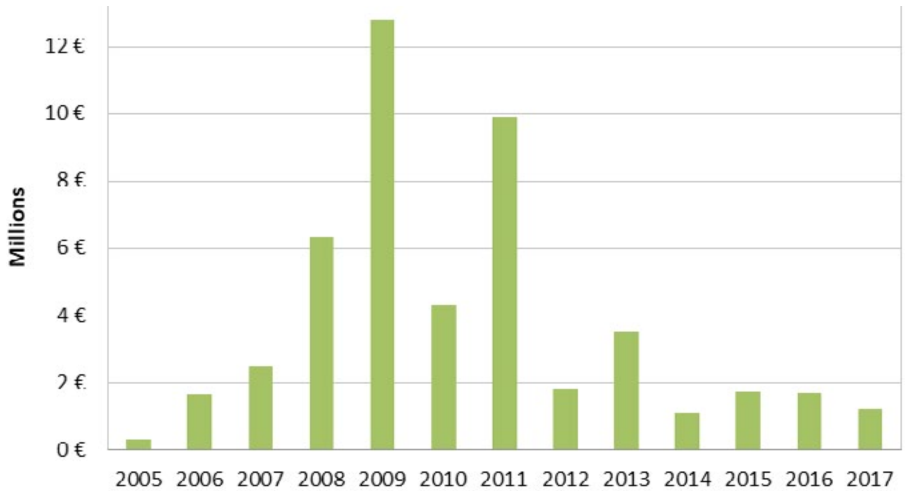


Figure 3. National R&D funding for wind energy related projects by Tekes (BusinessFinland as of January 2018); funding to research organizations represents usually 60% of the project budget

Collaborative Research

VTT is active in several EU, Nordic, and IEA research project frameworks. Within the IEA Wind TCP Finland takes part in:

- Task 11 Base Technology Information Exchange produces valuable information in identifying issues important for wind R&D in Finland
- Task 19 Wind Energy in Cold Climates (Operating agent VTT) brings results to developers in Finland. Task 19's Recommended Practices report sub-chapter on ice throw helps the work of the Finnish Wind Power Association (FWPA) in preparing safety guidelines.
- Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power (Operating agent VTT) is linked to research projects VaGe, EL-TRAN and NeoCarbon.
- In 2017, Finland gave up the membership in Task 31 WAKEBENCH: Benchmarking of Wind Farm Flow Models.
- Task 36 Forecasting for Wind Energy (Vaisala, VTT, and FMI) is linked to national project VaGe.
- Task 28 membership was renewed in 2017, as Acordi, supported by Energy Industries and FWPA, are gathering the inputs from Finland to this international collaboration.

IMPACT OF WIND ENERGY

Environmental Impact

Given the structure of electricity generation in Finland, the initial effects of wind power on greenhouse gas emissions would be about 700 g CO_2/kWh. Thus, wind power production saved up to 3.4 million tons of CO_2 in 2017. This reduction of CO_2 helped bring the emissions of all power generation in Finland down to 89 g/kWh in 2017 (103 g/CO_2/kWh in 2016).

According to a study by Sweco Environment Ltd, approximately 4,200 people will be employed in wind power planning, construction, and O&M by 2020. More than 20 technology and manufacturing companies are involved in wind power in Finland. Several industrial enterprises have become global suppliers of major wind turbine components.

Economic Benefits & Industry Development

Locally, the municipality receives property tax revenue wind power. Depending on the power plant value and the municipal tax rate, the annual real estate tax of 3-MW wind turbines is 6,000-11,500 EUR/yr (7,200-13,800 UDS/yr). This is significant additional income for some small municipalities. The real estate tax that one wind power plant generates for the municipality during its life cycle, depending on the investment cost and the real estate tax rate, is approximately 100,000-200,000 EUR (120,000-240,000 USD).

Finland's technology sector is employing 2,000-3,000 people. Development and Operation and Maintenance (O&M) has led to an increase in direct and indirect employment, with 2,200 jobs in 2015. This figure will decrease in 2018, as wind farm development has slowed or stopped due to the FIT system closure prior to the coming auction-based support scheme.

There are more than 100 companies in the whole value chain, from development and design to O&M and other service providers, with the majority of wind farm planning and construction happening domestically.

For example, Moventas Wind is the largest independent global manufacturer and service provider of gears and mechanical drives for wind turbines. ABB is a leading producer of generators and electrical drives for wind turbines and wind farm electrification (both land-based and offshore). The Switch supplies individually-tailored permanent magnet generators and full-power converter packages to meet the needs of wind turbine applications, including harsh conditions.

Finland produces many materials for prominent wind turbine manufacturers, such as cast-iron products and tower materials (SSAB, formerly Rautaruukki) and glass-fiber products (Ahlstrom Glasfiber). Sensors, especially for icing conditions, are manufactured by Vaisala and Labkotec. Peikko offers foundation technologies based on modular components.

A growing number of companies offer O&M services in Scandinavian and Baltic markets, including Bladefence, JBE Service, and Wind Controller. Norsepower is the leading provider of low-maintenance, software-operated and data-verified auxiliary wind propulsion systems.

NEXT TERM

Following the strategy, the technology-neutral tendering process to acquire renewable-based generation capacity will start in late 2018. The government limited the tendering scheme to 1.4 TWh of cost-effective electricity production from renewable energy (originally 2 TWh) and rolled the tendering in a single round instead of the original plan of two phases. The approved projects will receive a feed-in tariff. The Energy Authority is preparing the details of the tendering process, which is subject to final approval by the government.

Because of these circumstances, less new capacity is expected to be constructed in 2018 compared to 2017. Some of the developed projects have applied for a special investment grant for renewable technology projects with new technology innovation, but with no success.

References

Opening photo: Kayaking in the Pori offshore wind farm (Source: Hannele Holttinen)

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