



Report 2021

Norway

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Wind power in Norway continued with a fairly high-level of deployment, resulting in 706 MW of new installed capacity in 2021 and a net total installed capacity of 4649 MW at the end of the year.

The electrical energy produced by the 64 active wind farms in 2021 was 11.8 TWh. That is an increase of 19% from the year before, despite lower-than-normal wind resource availability. Decreasing LCOE of wind power projects, favourable depreciation rules, and the end of the electricity certificate scheme have driven the latest years' high-level deployment of wind power in Norway.

There is significant activity in the regulatory space for both onshore and offshore wind power. Several processes are ongoing for the improvement of the licensing scheme for onshore wind power. Simultaneously the framework for offshore wind is under development. Neither of these processes were completed in 2021.

Table 1. Key National Statistics 2021: Norway

Total (net) installed wind power capacity	4.649 GW
Total offshore capacity	0.006 GW
New wind power capacity installed	0.706 GW
Decommissioned capacity (in 2021)	0.037 GW
Total electrical energy output from wind	11.8 TWh
Wind-generated electricity as percent of national electricity demand	8.5%
Average national capacity factor	32.9%
Target	N/A
National wind energy R&D budget	

Highlight(s)

- The onshore wind power deployment in Norway slowed down in 2021, with 706 MW of new installed capacity. That is less than half of the annual installed capacity of the previous year.
- The total electrical energy output from wind increased by 19%, despite lower-than-normal wind resource availability, this was due to the increase in installed capacity.

Market Development

Targets and Policy

The total electricity production in 2021 in Norway was 157.1 TWh. Renewable sources of electricity amounted to 98.9% of the national electricity production, where 7.5% of the electricity produced came from wind power. With a Norwegian electricity demand totalling 139.5 TWh for the year, Norway exported 17.6 TWh of electricity to our neighbouring countries.

There has been an incentive mechanism for increasing renewable energy production in Norway. This was a

joint support scheme with Sweden with the aim of financing 28.4 TWh/yr of new renewable energy production by the end of 2021. In the scheme, 13.2 TWh was to be financed by Norwegian power consumers. This market-based electricity certificate scheme was both country- and technology- neutral. The objective was to allow the market to dictate the type of renewable energy production and where it is built. In practice, this means that Norway has no explicit target for national renewable production or for wind production as such. However, the electricity certificate scheme has been successful in incentivising investment decisions for the deployment of new wind energy installations in Norway over the last years. The combined 28.4 TWh/yr target has been met. The deadline to subscribe to the scheme in Norway was the 31st of December 2021. In Sweden, the scheme closes for subscription in 2035.

No new incentive mechanisms or capacity targets has been introduced. On the contrary, the Norwegian parliament agreed on a production tax for electricity produced by onshore wind power plants.

A guidance outlining the process for allocating areas for offshore wind power was sent to a public hearing for input by the public. The guidance is now under review. Some regulatory details are yet to be decided before the potential developers can send applications for the offshore areas opened previously under the Offshore Energy Act.

Progress and Operational Details

Deployment of Norwegian wind power plants has increased dramatically in the last five years, and the last three years have been the strongest on record. In 2021, 706 MW of new capacity was commissioned. All this growth has been onshore.

Six projects were fully commissioned in 2021, and four additional projects started producing electricity. Adding to this, one project was repowered. The sizes of the projects varied from 3 to 72 wind turbines.

All projects use modern turbine technology, and all projects use generators 4.2 MW or larger. The maximum generator capacity was 5.7 MW, and this was used in two of the



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ten projects. Rotor diameters varied from 117 to 150 meters. Tower heights show no significant increase since 2020, with 144 meters hub height as the highest installed wind turbine this year.

Wind resources in 2021 were lower than normal, resulting in a capacity-weighted production index for Norwegian wind farms in 2021 of 93.6%. The average capacity factor for Norwegian wind farms in normal operation was 32.9%.

TetraSpar, a new demonstrator for a floating offshore wind turbine concept, was installed. The demonstrator has a new floating foundation concept with a tubular steel main structure and a suspended keel. The capacity of the demonstrator is 3.6 MW.

Matters Affecting Growth and Work to Remove Barriers

This year marked the end of the electricity certificate scheme, and there are no new policies to incentivize further wind power deployment in Norway. Onshore projects are now at grid parity and will not need further economic incentives for develop-

ment. However, some barriers exist for further wind power deployment from 2022 and onwards. In the short term the most definitive barrier is the lack of new licenses.

In 2019, the Norwegian authorities announced that no new wind power applications would be considered until changes to the permitting system were in place. There has been an exception for projects that have applied at an earlier stage and have support from the municipality. The permitting system is subject to an ongoing revision that has not yet been implemented. In general, the changes being made to the permitting system are meant to improve the system and reduce the level of conflict, which has been high in the later years. Regardless of the re-opening of the application process, the current lack of licenses, and the fact that most of the existing projects had deadlines for commissioning by the end of 2021 means that few wind farms will be deployed between 2022 and forward.

The government has opened two offshore areas for applications for permits. As of the end of 2021, the

process for application is not finalised, and no applications have been received or processed. The estimated cost of building offshore wind power is still high compared to grid parity in Norway based on assessments of the average future power price, both for floating and bottom fixed offshore wind. The physical potential for floating offshore wind is higher than for bottom fixed due to a large exclusive economic zone with primarily deep waters. There has been signalled some form of support for offshore wind projects – specifically floating offshore wind projects, but there has been no official decision on a support scheme.

R,D&D Activities

There is a lot of movement in the Norwegian R,D&D space. The Research Council of Norway administers a public research program for sustainable energy, ENERGIX. This program covers renewable energy, energy efficiency, energy systems, and sustainable transport (hydrogen, fuel cells, biofuels, and batteries). This program is open for industry, research institutes, and universities

that can receive funding for their research based upon proposals to regular calls.

For demonstrators and prototypes, there is two governmental support mechanisms. Firstly, The Norwegian energy agency, Enova, offers capital grants for full-scale demonstration projects of ocean renewable energy production, including offshore wind. While up to 50% of eligible costs can be covered, Enova's funding measured in absolute figures is limited. Secondly, Innovation Norway runs a program supporting prototypes with in environmentally friendly technology. Wind energy is included in this definition; here, projects are supported with up to 45% of eligible costs.

National R,D&D Priorities and Budget

The Norwegian national strategy for research, development, demonstration, and commercialization of new energy technology is called Energi21. Offshore and onshore wind are included in this strategy, where the prioritised subjects are outlined below.

The R&D priorities for offshore wind are:

- Optimal foundations for both seabed-based and floating turbines and different seabed conditions.
- Concepts and systems for reliable electric infrastructure (offshore subsea solutions).
- Cost-effective, time-saving assembly and installation of offshore wind farms.
- Efficient concepts for marine logistics (heavy maintenance) and robust solutions for access.
- Concepts and systems for reducing operational and maintenance costs and increasing energy conversion.
- Ratios.
- Enhanced knowledge about offshore wind power's environmental and societal impacts.

The R&D priorities for onshore wind are:

- Wind resources (prognoses).
- Cost-effective operation and maintenance and technology.
- Environmental and societal issues.

The budget for the ENERGIX program in 2021 was 540 million NOK (54 million EUR; 61 million USD), and the same budget is expected for 2022. In total, the Research Council granted 84 million NOK (8,4 million EUR; 9,5 million USD) to wind energy research in 2021. In 2021 the ENERGIX program granted funding to the following wind energy R&D projects:

- Development of a cost-competitive installation method for offshore wind farms, ISQ AS (Industrial innovation project)
- High Voltage Subsea Connector for Offshore Wind, Baker Hughes Scandinavia AS (Industrial innovation project)
- Seabed Cone Pressure meter for in-situ testing of soil and rocks for strength and stiffness parameter for offshore windfarm foundation, EXCESS ENGINEERING AS, (Industrial innovation project)
- Cyber-physical empirical methods for lattices of marine structures, SINTEF OCEAN AS, (Competence building project)

A new center for offshore wind was also established in 2020, NorthWind. The center is run by Sintef Energy and has 20 industrial partners and 5 academic partners. The center will be run for 8 years and has a yearly budget of about 44 million NOK (4,4 million EUR; 5,0 million USD). Public funding is 50% of this budget.

In total, 17 wind R&D projects were funded by ENERGIX in 2021. Twenty five industrial companies and five research institutes are involved in these projects.

National Research Initiatives and Results

The ENERGIX program supports several "Knowledge building projects for Industry" at Norwegian research institutions. These are large research projects with budgets of 20-25 MNOK that span 4-5 years and include education of PhD students. An example of this is the following project of cyber-physical empirical methods for lattices of marine structures (CYBERLAB) at Sintef Ocean (2021-2025), where the aim of CYBERLAB is to enable low-carbon offshore power grids in the form of large lattices of marine structures. The expected results and industry benefits are:

- To develop cyber-physical empirical methods to calibrate models of large lattices of marine structures. These methods will be applied to component (cell) characterisation and full system (lattice) verification.
- Maximise the information gained from cyber-physical testing by using Optimal Experimental Design. OED provides a mathematically sound framework to optimally set the parameters of an experiment before its execution in an adaptive and automatic way.
- Contribute to the understanding of the dynamic behaviour of lattices of marine structures.
- Demonstrate the effectiveness of the proposed approaches for a specific offshore power grid application, such as a floating wind or solar park with shared mooring.

Test Facilities and Demonstration Projects

TetraSpar, a new demonstrator for a floating offshore wind turbine concept, was installed. The demonstrator has a new floating foundation concept with a tubular steel main structure and a suspended keel. The capacity of the demonstrator is 3.6 MW.

Collaborative Research

In 2021, Norway participated in the following IEA Wind Tasks:



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- Task 11 Base Technology Information Exchange
- Task 19 Wind Energy in Cold Climates
- Task 25 Power Systems with Large Amounts of Wind Power
- Task 26 Cost of Wind Energy
- Task 29 Mexnext Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models
- Task 30 Offshore Code Comparison Collaboration Continuation with Correlation (OC5)
- Task 32 Lidar Systems for Wind Energy Deployment (LIDAR)
- Task 34 WREN - Working Together to Resolve Environmental Effects of Wind Energy (WREN)
- Task 37 Wind Energy Systems Engineering: Integrated R,D&D.

There were also processes ongoing for joining several new Tasks, including:

- Task 43 Wind Energy Digitalization

- Task 44 Flow Farm Control
- Task 45 Recycling of Wind Turbine Blades
- Task 46 Erosion of Wind Turbine Blades
- Task 49 Integrated DDesign on Floating wind Arrays (IDEA)

Impact of Wind Energy

Environmental Impact

Norway has a renewable ratio in electricity generation of 98.9%. This means that new electricity generation from wind power to a small degree, displaces electricity production from fossil fuels, directly. In that regard, the direct effect of new wind power capacity on greenhouse gas emissions from electric energy generation in Norway is limited. On the other hand, larger volumes of affordable renewable energy coupled with CO₂ reduction targets are

driving the electrification of transport and industry, which is the sector behind the majority of Norwegian fossil fuel consumption. Driven by this and new industries, Norwegian power demand is expected to increase, and wind power – onshore and offshore – is well suited to meet that demand, based on resource availability and the low LCOE of onshore wind power. However, there are high levels of concern and resistance in the public tied to wind power development's impact on the local environment, which led to the stop in licensing of onshore wind power in 2019.

Economic Benefits and Industry Development

Development and ownership of onshore wind power projects have traditionally been dispersed among local energy utility companies. Foreign investment has become increasingly common in newer Norwegian wind

power projects, and foreign ownership accounts for the majority of total ownership. Large national energy companies or local energy utilities operate some of these projects on behalf of their owners. Several Norwegian companies such as Fred Olsen Renewables, Statkraft, and Equinor are active internationally.

There is no wind turbine manufacturing industry in Norway, but there are companies delivering sub-supplies to wind turbine manufacturers. We see several industry initiatives toward offshore wind, especially the floating offshore wind industry. Companies with experience in the offshore oil and gas industry have widened their scope of interest and increased their engagement with the offshore wind industry. These companies normally offer expertise in marine operations, offshore structures, mooring solutions, logistics, consulting, and more. One example is the HVDC platforms for the Dogger Bank projects that will have project management and completion in Haugesund, Norway. There are also offshore cable manufacturing facilities in Norway.

Next Term

In the next term, there will be an installed a moderate amount of new onshore wind power in Norway. The installed wind power capacity is expected to be approximately 5 GW by the end of 2022. After that, little new onshore wind power capacity is expected in Norway before the end of this decade due to a lack of new licenses. There will not be any support schemes available for onshore wind, and a moderate production tax is expected to be implemented for onshore wind in 2022. That means wind power built in Norway after 2021 will need to be profitable on its own and with the added tax burden.

There has been a shift of focus towards the offshore wind in both the public debate and stakeholders. The government has stated that the development of Sørlige Nordsjø II – the larger area suited for bottom

fixed technology – will happen in two phases. The first phase can only be connected to Norway. The second phase will be open to other grid options. Several processes are ongoing. The two opened offshore areas are divided into smaller entities suitable for allocation. The criteria for allocation and the process for allocating these areas are under development by the Ministry of Petroleum and Energy. An investigation of grid connection alternatives and their impact on the Norwegian power system, consumers, and producers are ongoing at the Norwegian Water Resources and Energy Directorate. The same is an evaluation of market design of offshore wind power in Norway. The ministry has also instructed the Norwegian Water Resources and Energy Directorate to identify newly suitable areas for offshore wind development.