SOURCE: SIMON OLDANI_NVE

NORWAY

Wind power in Norway continued with a high level of deployment and increased by 1532 MW in 2020, resulting in a net total installed capacity of 3,977 MW at the end of the year. The production of wind-based electrical energy in 2020 was 9.9 TWh, an increase of 80% from the year before. Decreasing LCOE for wind power projects and the end of the electricity certificate scheme drives the high level of wind power deployment in Norway in recent years.

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TABLE 1. KEY NATIONAL STATISTICS 2020: NORWAY

Total (net) installed wind power capacity*	4 GW
Total offshore capacity	0 GW
New wind power capacity installed	1.5 GW
Decommissioned capacity (in 2020)	0 GW
Total electrical energy output from wind	9.9 TWh
Wind-generated electricity as percent of national electricity demand	7.4%
Average national capacity factor**	32.1%
Target	N/A
National wind energy R&D budget	5.1 million USD

*Installed wind power capacity: Use nameplate power ratings of the installed wind turbines

Average National Capacity Calculation: Only include turbines in operation the whole year: **(MWh production/8,760 hrs) / MW installed capacity MWh total electrical production from wind turbines operating 1 January through 31 December divided by 8,760 hrs divided by the total installed wind capacity (in MW) at the beginning of the year.
[You can also use an estimate based on the average installed capacity during the year: (installed 1 Jan + installed 31 Dec)/2. But in that case, state that this is how the estimate is calculated.]

In December, a white paper about the permitting system for onshore wind power in Norway was considered by the Parliament. This initiated a governmental process that may lead to several changes to the permitting system.

A new R&D centre for offshore wind, NorthWind, was established. The centre will open in 2021 and run for eight years with an annual budget of about 5.1 million USD. R&D activities are mainly focused on offshore wind power and floating offshore in particular.

The key statistics for 2020 are shown in Table 1.

Market development

Targets and policy

Total electricity production in Norway in 2020 was 154.2 TWh. Renewable sources of electricity amounted to 98.3% of the national electricity production of which 6.4% came from wind power. With electricity demand in the country totalling 133.7 TWh for the year, Norway exported 20.5 TWh of electricity to its neighbouring countries.

As a member of the European Economic Area (EEA), Norway agreed—after a lengthy political process—to accept the EU's renewable energy directive in 2011. The target for renewable energy was set to 67.5% of total energy consumption by 2020. Norway is meeting this target through a combination of increased renewable energy production and energy efficiency measures.

The incentive mechanism for increasing renewable energy production in Norway is a joint support scheme with Sweden to finance 28.4 TWh/yr of new renewable energy production by 2021, of which 13.2 TWh is to be financed by Norwegian power consumers. This incentive structure gives both countries the right to account for 50% of the new renewable production within the total target of 28.4 TWh/year in their national renewable energy target that they report to the EU Commission. This market-based electricity certificate scheme is both country- and technology-neutral. The objective is to allow the market to dictate what type of renewable energy production and where. In practice, which means that Norway has no explicit target for national renewable production, or for wind production as such. However, the electricity certificate scheme has resulted in investment decisions for the deployment of considerable new wind energy installations in Norway over the last five years.

The target has now been achieved, partly due to the high amount of wind power deployment in Norway and Sweden. Norway has not introduced any new targets for renewable energy deployment. The Norwegian government published a white paper on the permitting system for onshore wind power in Norway in the summer of 2020, that was subsequently considered in the Parliament in December. The main outcomes of the consideration were changes to the permitting system such as improved coordination with other legal frameworks, introduction of site-specific height

SOURCE: THOMAS MO WILLIG_NVE

limitations to wind turbines, and an assessment of how compensation to local municipalities can be introduced.

About the same time as the white paper was published, two areas for offshore wind were opened for applications under the Offshore Energy Act. Offshore wind energy can only be deployed in areas that are opened under this act. Some regulatory details have yet to be decided before the potential developers can submit applications, but this is a big step towards future deployment of offshore wind production in Norway.

> Wind power deployment in Norway was at a record high in 2020 with 1532 MW new capacity installed. This was almost double the previous record set in 2019.

Progress and operational details

Deployment of Norwegian wind power plants has increased dramatically over the last five years. A record-high 1,532 MW was commissioned in 2020, and over 1,100 MW of wind power capacity was under construction in Norway at the end of the year, all onshore.

Fifteen projects were fully commissioned in 2020, and one additional project started producing electricity. Adding to this, one project was re-established. The sizes of the projects varied from 7 to 47 wind turbines. Costs for the projects stayed relatively unchanged from the previous year, and a preliminary estimate of the weighted average LCOE for the fully commissioned projects was 28 EUR/MWh.

All projects use modern turbine technology and all projects used generators above 4 MW. The maximum generator capacity was 4.3 MW, and this was used in five of the fifteen projects. Rotor diameters varied from 117 to 150 meter, mostly accommodating for IEA Class II wind sites. Tower heights are also increasing, with 145 meters hub height as the highest installed wind turbine in Norway so far. This was at the only inland site to be commissioned in 2020. The remaining sites were along the coast.

Wind resources in 2020 were higher than normal, resulting in a capacity-weighted production index for Norwegian wind farms in 2020 of 108.7%. The average capacity factor for Norwegian wind farms in normal operation was 37.4%.

Matters affecting growth and work to remove barriers

The end of the electricity certificate scheme is approaching, 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 development. However, there are some barriers for further wind power deployment from 2022 and outwards. The most important of these barriers may be 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. As of April 2021, this is still the case. The changes to the permitting system are meant to reduce the level of conflict, which has been quite high for some years, and the government has stated that it wants to facilitate a long-term development of wind power in Norway. Regardless of the system changes, the current lack of licenses and the set deadline of December 2021 for existing licenses means that few wind farms will be deployed from 2022 until 2027/2028.

The government has opened offshore two areas for permit applications. At the time of writing, this process is not finalized, and no applications have been received. The estimated cost of building offshore wind power is still high compared to grid parity in Norway, both for floating and bottom fixed offshore wind. The physical potential for floating offshore wind is higher than for bottom fixed due to the high share of deep waters. There has been no official decision on how and if offshore wind power developers can apply for government funding when they apply for permits. A government white paper on this topic is in the making and is expected to be published in the first half of 2021. Alongside the white paper, the government has signalled that it will publish a guidance document for the application process for offshore wind power plants.

R,D&D activities

The Research Council of Norway administers a public research programme for sustainable energy, ENERGIX. This programme covers renewable energy, energy efficiency, energy systems, and sustainable transport (hydrogen, fuel cells, biofuels, and batteries). Industry, research institutes, and universities may receive funding for their research based upon proposals to regular calls.

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. Innovation Norway runs a programme supporting prototypes within environmentally friendly technology. Wind energy is included in this definition. Projects are supported with up to 45% of eligible costs.

National R, D&D priorities and budget

Energi21 is the Norwegian national strategy for research, development, demonstration, and commercialization of new energy technology.

SOURCE: SIMON OLDANI_NVE

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 programme in 2020 was 52.7 million USD and the same budget is expected in 2021. In total, the Research Council granted 7.6 million USD to wind energy research in 2020. In December 2020, the ENERGIX programme granted funding to the following wind energy R&D projects:

- HONEYMOORING – Efficient mooring of floating offshore wind parks, Semar AS (Industrial innovation project)
- Improved accuracy, security and efficiency for floating offshore wind analysis, DNV GL AS (Industrial innovation project)
- Mooring Optimization for Large Floating Wind Turbines, National Oilwell Varco Norway AS, (Industrial innovation project)
- Key research challenges in the development of a Lowerable Offshore Floating Turbine, Blue wind as, (Industrial innovation project)

In total 18, wind R&D projects were funded by ENERGIX in 2020, and 25 industrial companies and five research institutes are involved in these projects.

SOURCE: KRISTIN EVJEN_NVE

National research initiatives and results

A new centre for offshore wind was also established, NorthWind. The centre will be run by Sintef Energy and has 20 industrial partners and 5 academic partners. The centre will run for 8 years and has an annual budget of about 5.1 million USD starting in 2021 of which 50% comes from public funding.

The ENERGIX programme supports several 'Knowledge-building Project for Industry' projects at Norwegian research institutions. These are large research projects with budgets of 20-25 million NOK, run over 4-5 years, and include education of PhD students. Here is an example:

'Upscale': Institute for Energy Technology (2019-2022)

- Objective: Build knowledge about the next generation 25MW floating wind turbines and the technologies need to enable them.
- Expected results and industry benefits:

o realistic 25 MW reference semi-submersible floating wind turbines. The new advanced rotor aerodynamics models needed. Improved load reducing control systems

- Insight into the next generation of very large floating wind turbines

- Tools needed to design and analyse such FOWTs

Collaborative research

In 2020, Norway participated in the following IEA Wind Tasks:
Task 11 Base Technology Information Exchange; Task19—Wind Energy in Cold Climates; Task 25 Power Systems with Large Amounts of Wind Power; Task 26 The 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 Assessing Environmental Effects and Monitoring Efforts for Offshore and Land-Based Wind Energy Systems and Task 37 Wind Energy Systems Engineering: Integrated R, D&D.

Impact of wind energy

Environmental impact

Norway has a renewable ratio in the electricity generation of 98.3%. Concerns about wind power development's impact on local environment and public debate culminated in 2019 when the national framework for wind power was released by the government. In the aftermath of this, the government has published a white paper about the entire permitting system for onshore wind power in 2020. The outcomes of this white paper are now being assessed by the government bodies and changes to the permitting system are in progress.

Economic benefits and industry development

Development and ownership of wind power projects have traditionally been dispersed among local energy utility companies. Foreign investment is becoming increasingly common in Norwegian wind power projects, and for the wind parks that are operating by the end of 2019, foreign ownership accounts for 62% of the total ownership. Large national energy companies or local energy utilities operate some of these projects on behalf of the owners. Some Norwegian companies, like Fred Olsen Renewables, Statkraft and Equinor, are or have been engaged in projects in foreign countries, like offshore wind in the United Kingdom.

There is no significant wind turbine manufacturing industry in Norway, but there are companies delivering sub-supplies to wind turbine manufacturers. Also, we see several industry initiatives towards offshore, and especially floating offshore, wind industry. Companies with experience from the offshore oil and gas industry have widened their scope of interest and increased their engagement to the offshore wind industry. These companies offer offshore wind turbine substructure solutions based on their extensive knowledge from operations at sea. Other companies specialize in support systems, anti-corrosion technology or site optimization modelling.

Next term

The next term will be dominated by the construction of large amounts of new wind power onshore in Norway. Installed wind power capacity is expected to reach nearly 5 GW by the end of 2021. Norway will not continue with the electricity certificate scheme, which means that wind power built in Norway after 2021 will need to be profitable on its own without a possible additional income from the certificate scheme. An overshoot of the target in the common electricity market has driven the price of the certificates down, thereby making the end of the certificate scheme less important for new investment decisions. In addition, the permitting of onshore wind farms is put to a halt while the decisions from the Parliament as an aftermath of the wind power white paper are implemented. A shift of focus towards offshore wind is already taking place, both in the public debate and the focus of the stakeholders.

References

List any references used directly in the text of the chapter.

- DO NOT use automatic footnotes, formatting, or automatic numbering in MS Word. *They become lost during the text translation process for layout; texts containing automatic numbering will be returned to the author for revision.*

- Place the numbered reference at the end of the sentence in brackets [1]. For example, "…The Ministry of Economic Affairs finalized the Connect 6,000 report in May 2008 [1]."

- Use the following format for citation under the reference heading: [1] Author (year) Title of report or document. Download from (provide website link).