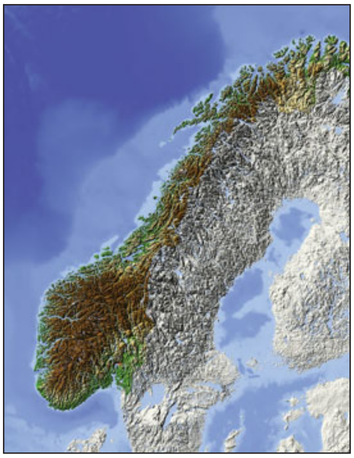

Norway faces windy road to offshore wind

By **Angela Saini**
Feature Editor
John Olav Giæver Tande

There is little that the world can teach Norway about renewable energy. Around 96% of its electricity already comes from hydropower, and it is so cheap that some is exported to its neighbors, including Germany and Denmark. But there is limited capacity to building more hydropower in Norway, according to Jon Samseth, adjunct professor in the Department of Chemical Engineering at the Norwegian University of Science and Technology in Trondheim. With a long windy coast facing the Norwegian Sea, offshore wind power could therefore be an alternative source of renewable energy in the future. Indeed, Norway has considerable expertise in the wind industry. Promising though this could be, however, it comes with challenges.

The infrastructure needed to harness offshore wind power is considerable. It includes bottom-fixed or floating substructures with large wind turbines generating electricity; substations and submarine cables for collecting and transporting the electricity to shore; and systems for operation, control, and maintenance of the installations. Land-based and offshore wind turbines are similar in design, usually built according to the classical horizontal-axis wind turbine concept, and up to seven megawatts, with rotor diameters approaching 160 meters (even larger units are in development). Wind farms may range from a few tens of megawatts onshore, but can be gigawatts offshore.

Despite being an enormous potential source of power, the main challenge for offshore wind, said John Olav Giæver Tande, Director of Norway's Research Centre for Offshore Wind Technology (NOWITECH), is cost. Offshore wind farms need to operate under some of the toughest environmental conditions on the planet, over time scales of 20 years or more. "It is one of the big engineering challenges of the century. This calls for accelerated research and innovation for value creation, and reducing risks and costs," he noted. As far as materials research goes, this demands a better understanding of materials degradation in the harsh offshore conditions.

While land-based wind turbines are a common sight across Europe—covering around 10% of the EU's electricity consumption in a typical wind year, according to the European Wind Energy Association—offshore wind is far more rare. As of February 2015, there were 128.8 gigawatts of installed wind energy capacity in Europe, of which 120.6 GW were onshore and just over 8 GW were offshore. Europe dominates offshore wind development; only 0.7 GW of offshore wind is installed outside Europe, though the United States, Japan, and other countries have ambitious plans to develop more offshore wind farms in the future.

Jason Jonkman, a senior engineer at the National Wind Technology Center in the United States, noted that although Denmark, Germany, the UK, and The Netherlands are the biggest investors in offshore wind, Norway has been strong in funding offshore wind research and development through NOWITECH and the Norwegian Centre for Offshore Wind Energy (NORCOWE).

Norwegian energy firms have also built up a particular expertise in these environments through their work on offshore oil rigs. Norway-based energy firm, Statoil and Statkraft, for instance, have become key to the global offshore wind industry. Among other large projects in the UK, in February 2015, they were granted consent to develop 2.4 gigawatts of offshore wind capacity at Dogger Bank.

While the UK takes advantage of Norwegian expertise in offshore wind, Norway itself has been slow to adopt the technology. One sticking point is transmitting power to where it is needed, which is often at some distance inland from the offshore wind sites. Large offshore wind farms require an underwater high voltage direct current connection, which is both an expensive and fairly young technology. Tande suggested that there is "significant international interest in developing an offshore grid with transnational lines serving both power exchange and connecting offshore wind farms." Research and development efforts around projects such as these may lead to cost savings in the future, along with fewer risks in grid connection and power system integration.

Another technical obstacle to the growth of offshore wind is the development of larger and more robust turbines and components especially adapted to the salty, wet and cold offshore environment. Since offshore turbines tend to be larger, weight is also a problem. The weight of the tower top increases more or less with the cube of the rating. Innovations are required for larger and more lightweight designs, which could incorporate the use of new materials, along with improved blade designs and new generator concepts. "Blade design must change through the use of different composite materials such as carbon versus glass; advanced design techniques such as additional flexibility and bend-twist coupling; or advanced sensors, actuators, and controls," said Jonkman.

"Since offshore blades will most likely be even larger than onshore blades, buckling and high quality adhesive joints become very important," added Andreas Echtermeyer, Professor of Composites and

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Polymers at the Norwegian University of Science and Technology. "A good understanding of fatigue and resistance to salt spray is also important."

Echtermeyer's team has been developing solutions to these exact problems. "We worked on blades with special composite layers that allow coupling of bending and twisting. This feature would simplify the control systems, since the blades automatically pitch. However, this work has not been implemented commercially yet and needs some more research," he said. Materials they have used are various combinations of hybrid laminates of carbon fibers and glass fibers.

Operators also need more knowledge about wind and wave conditions, and better models for wind farm designs that can reduce uncertainty and create high energy yields. Key areas for research include more resilient designs with less need for maintenance and repairs, systems for reducing the need for access, and vessels capable of accessing turbines in rough weather—all of which pose materials challenges.

One novel process that may be useful for these applications is Thermasic, the thermal spraying of silicon carbide, which was co-invented by Nuria Espallargas, a professor, and Fahmi Mubarok, a researcher, both in the Department of Engineering Design and Materials at the Norwegian University of Science and Technology. This can create an extremely hard, wear-resistant, low-friction ceramic coating that can be applied to rotating machinery, such as the main bearings in large direct drive wind turbines. "The coatings are totally new in the field of thermal spray," said Espallargas.

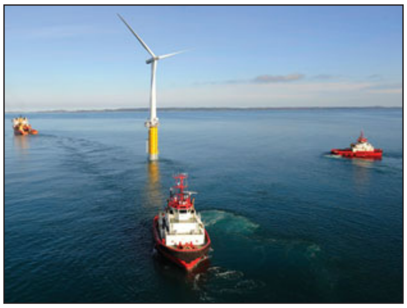
Similar research is also being pursued at SINTEF, the Foundation for Scientific and Industrial Research in Norway. "From the offshore oil and gas industry, we know that maintenance and repair work of corrosion protective coating systems applied in the atmospheric zone are necessary after eight to ten years. Coating systems satisfying the 20- to 25-year lifetime, which is demanded for offshore wind turbine, are available, for example duplex coating systems consisting of thermally sprayed zinc and a three-coat paint system. However, they are generally expensive," said Astrid Bjørgum, a senior advisor in materials and chemistry at SINTEF.

In an effort to reduce costs, Bjørgum and her team have been looking at reducing the film thickness of thermally sprayed coatings, reducing the dry film thickness of paint systems, and cutting the number of coats of paint to one or two instead of three. They have also tried to modify existing corrosion protective paints by adding nano- and microparticles, or capsules containing corrosion inhibitors.

Out at sea, the biggest engineering hurdle to overcome when installing offshore turbines is securing the foundations, especially at large depths. Substructures are available for bottom-fixed turbines, but only with very limited experience for water depths exceeding 50 meters, explained Tande. To solve this issue, Statoil has been piloting a full-scale floating windmill 10 kilometers off the southwest coast of Norway. Called Hywind, it is designed for depths of 100 meters or more. "Conditions for offshore wind in Norway are excellent, but as Norway has little shallow water acreage available, we needed to develop a floating technology in order to pave the ground for potential future offshore wind deployment," explained Trine Ingebjorg Ulla, the manager for offshore business development at Statoil.

Hywind has been operating successfully now for five years. "The benefits of floating wind are first and foremost that it greatly expands the acreage available for offshore wind deployment" she said. "The ability to mass produce the turbines, not having to adapt to the site conditions for each and every turbine, is favorable and will bring costs down when the supply chain matures. In addition, the fact that most of the assembly works can be done closer to shore in a more sheltered marine environment reduces installation time and risk, and enables use of more standard offshore vessels and cranes also used for the oil and gas industry." Kristin Guldbrandsen Frøysa, the director of NORCOWE, noted that floating turbines could be a renewable source of power for offshore oil rigs.

Ultimately, Norway's reticence to adopt offshore wind power comes down to capital costs, especially when weighed against extremely cheap existing hydropower. "With lower oil prices, there might be more of an interest to enter into alternative energy markets and thus more interest in offshore wind power. However, the cost of energy needs to be considerably lowered if we are to see offshore wind farms in the Norwegian coastal area" explained Frøysa.



Statoil's Hywind floating turbine being towed from Åmøyfjorden to Karmøy. Courtesy of Øyvind Hagen, Statoil ASA.

According to the strategic research agenda produced in 2014 by the stakeholder body, the European Wind Energy Technology Platform (TPWind), this could happen fairly soon. The technology and the market, it says, are just in their initial phases, and by 2030, the cost of offshore wind may fall to half its current level. The industry goal is a 20–40% reduction by 2020 and a 50% reduction in costs of energy from offshore wind farms by 2030, according to TPWind.

"In Europe alone, investments in the order of NOK 1000 billion (USD$122.7 billion) for construction of offshore wind farms are expected during the next 10 years. The international market is huge and in strong development," said Tande. Large areas with good wind resources offshore, along with increasing pressure on land space, indicates that a significant part of the growth of wind power may be offshore, possibly overtaking the land-based development, he added.

In Europe, the target is for 150 GW of offshore wind capacity by 2030, according to the European Wind Energy Association. Already, projects under construction in Europe will increase the installed capacity by one order of magnitude. With Norwegian researchers and companies playing such a large role in this growth, the hope is that it will be just a matter of time before Norway itself also takes advantage of offshore wind power. □

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