Floating offshore wind

Norway’s next offshore boom?

3 GW floating offshore wind by 2030 will cut Norwegian oil and gas industry emissions by one-third, contribute to emissions reduction in Europe, and presents a 5 billion USD potential for annual technology exports.

ZERO

Floating offshore wind power presents a tremendous opportunity for Norway to cut emissions of greenhouse gases and at the same time develop renewable solutions that Norwegian businesses and centers of expertise can deliver to a global market. Norway should aim to export at least 5 billion USD in equipment for the offshore energy industry by 2030, around ten percent of the world market. Achieving this requires a strong vision and a significant practice arena.

Floating offshore wind

Norway's vision of producing 3 GW of floating offshore power by 2030 and annual export revenue of 5 billion USD of offshore-related equipment can be achieved as follows:

- 1 GW offshore wind power by electrifying the oil and gas industry at the Norwegian continental shelf, cutting greenhouse emissions, and opening the first areas for offshore wind farms.
- 1 GW offshore wind power by using existing and future power-from-shore connections to oil and gas installations and connecting offshore power grids.
- 1 GW offshore wind power by connecting additional Norwegian offshore wind power to shore and to the continent.

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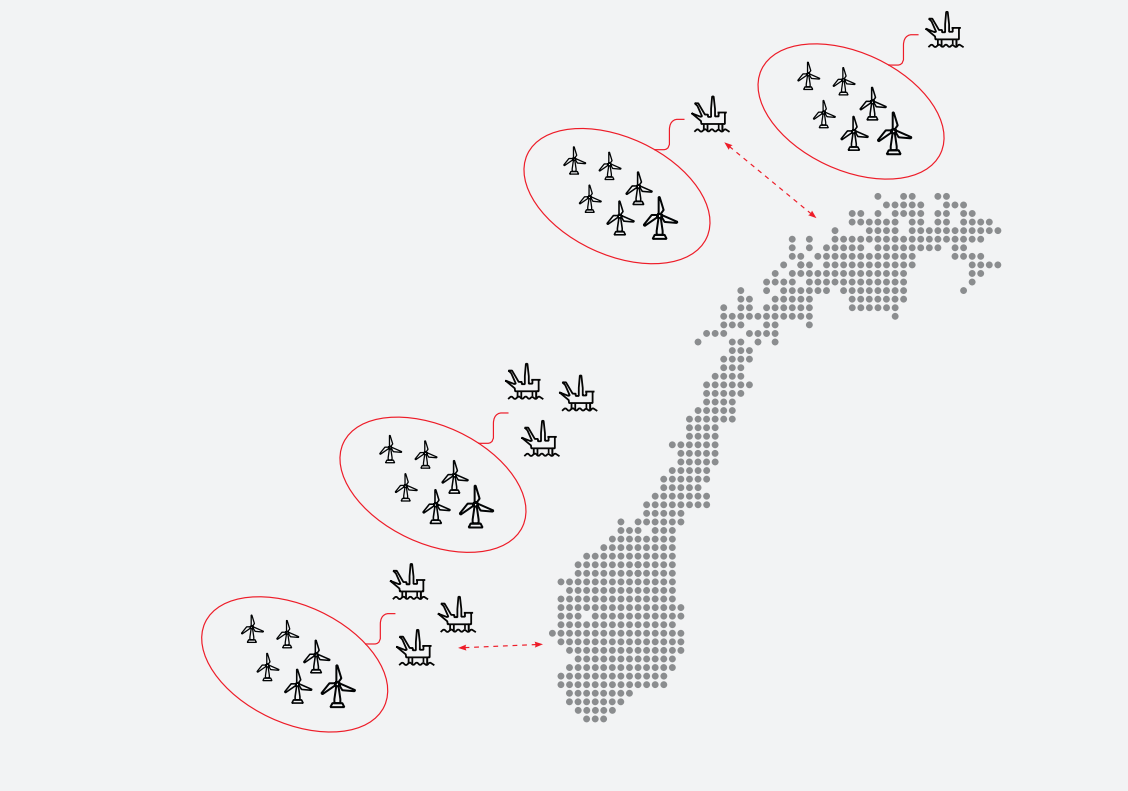
By electrifying offshore oil and gas installations in the North Sea with floating wind turbines, the oil and gas industry can act as a springboard for this new renewable technology across the globe.

This ambition requires a roadmap

Floating wind turbines are both a new export opportunity as well as a tool to reduce overall Norwegian emissions. By electrifying offshore oil and gas installations in the North Sea with floating wind turbines, the oil and gas industry can act as a springboard for this new renewable technology across the globe. The time to do this is now.

Practice makes perfect. Framework conditions are needed to achieve a sufficient volume of floating offshore turbine projects that can generate cost reductions. Agreeance with neighbouring countries including joint plans for infrastructure is essential to ensure proper scale and cost considerations are managed.

Norway's vision of reaching 3 GW from offshore wind turbines by 2030 and 5 billion USD in export revenues is achievable. To reach this goal there needs to be adequate framework conditions from the start. There needs to be a return for emissions reductions and the offshore oil and gas industry needs to be able to receive the power.



The concept for 3 GW offshore wind power by 2030

1 GW

1 GW of offshore wind power can be achieved by electrifying the Norwegian continental shelf (NCS), cutting greenhouse emissions, and opening the first areas for offshore wind farms. Up to 1,000 MW of gas-turbine generated power in petroleum installations can be replaced with electrical power from offshore wind power. Electrification will require various approaches and concepts. There will be some concepts where floating wind turbines supply single production installations and other solutions with production connected to multiple platforms. Equinor's proposed "Hywind Tampen" consists of an 88 MW wind farm that delivers to two different fields, Gullfaks and Snorre. Electrification will mean significant emissions reductions in Norway and will help develop a new climate solution. Power generated from natural gas power plants on the NCS have higher costs than onshore power. Therefore, floating wind turbines delivering power to a platform are therefore competing in a market where a higher willingness to pay prevails.

The completion of "Havsul" will contribute up to 350 MW of fixed-foundation offshore wind power. Opening of areas in accordance with the Offshore Energy Act for commercial wind farms can add a few hundred MW more.

2 GW

Connection of offshore wind power grids and power plants in hubs with an incipient expansion of an offshore electrical grid will make room for more floating wind turbines. Through greater sharing of turbines and gas power plants, the percentage of wind power that can be used increases and greenhouse emissions can be further reduced. Connection to existing onshore installations and expansion of new ones frees up even more room. A platform with consistent 50 MW power consumption and an onshore connection capacity of 50 MW opens the way for connection of up to 100 MW of wind power.

3 GW

Norway is adding new power cables to Germany and England totaling 2.8 GW. An additional 1.4 GW will go to Scotland, while renovation and potential expansion of the oldest part of the Skagerrak connection between Norway and Denmark is under discussion. Best practice would be to have floating offshore wind power in Norway connected to the power grids in other countries. Norwegian wind turbines can be connected to other countries' offshore wind projects that are connected to shore. An example of this would be the North Sea Wind Power Hub initiative, which involves the construction of an artificial island in the North Sea.

Cutting emissions with (floating) wind power

The current offshore oil and gas industry in Norway is operated by either power from shore or by local gas turbines. Production platforms on the Norwegian continental shelf that are electrified and currently operating include Troll A, Valhall, Gjøa, Martin Linge, and Goliat. In October 2018, Johan Sverdrup phase 1 was connected to the electrical grid. Other fields on Utsira High will also receive power from shore.

Another means of delivering power from shore is through floating wind turbines that supply one or more consumers. Equinor's "Hywind Tampen" project will power both the Gullfaks and Snorre fields. Flexible onboard gas power will thereby balance production with how much wind power is available. Equinor has estimated that wind power can thereby replace 35 percent of gas-turbine power. Integration (connection) between additional fields and power generation plants will be able to increase this percentage as will connection to land.

Several studies have been conducted on electrification of existing installations included in the area solutions[a]. There is great uncertainty around the initiative cost for emissions reductions and the potential is naturally dependent on the level of ambition. A common denominator among the studies carried out is that they point to the continuous development of new technology that can contribute to enabling the electrification of several types of new installations, and that offshore wind power infrastructure can be used for other purposes in the future.

The reports show that we are dependent on an overall output just under 800 MW to the various parts of the NCS to ensure a minimum level of electrification with reduction of 3 million tons of CO_2. This entails partial electrification of the southern North Sea, middle North Sea, northern North Sea and Norwegian Sea. There will be various solutions for the individual fields and areas including electrification of either individual installations, or multiple installations together. When it comes to the northernmost parts of the NCS, ABB and Rystad Energy conducted a study in 2017 of the potential for a power hub in the Barents Sea. Further development and future power needs will depend on the extent to which new areas and fields have opened to production, but partial electrification with an output requirement of 80–100 MW is realistic.

Power can also be delivered from floating wind turbines that supply one or more consumers.

In a report from 2015[b], Det Norske Veritas (DNV) discusses power inter-connection of different fields. This is being used at Ekofisk with good results. In this context DNV also points out the following, "When operations are far from shore, joint power generation, can supply a greater area. Power generation can take place through the use of combined power plants and/or offshore wind turbine farm."

With power from shore in the range of 800 to 900 MW, a realistic possibility to cut 3 to 4 million tons of CO_2 annually from existing fields has been reported. Equivalent power output from offshore wind power will result in slightly lower reductions in emissions in the range of 1–3 million tons of CO_2, and it will be necessary to coordinate power between multiple installations to reach the upper threshold of this range. Offshore wind in combination with power from shore will increase the potential for further emissions reductions.

a. Alternative power for the Norwegian continental shelf, Norwegian Oil Industry Association, 2007; Power from shore to the Norwegian continental shelf, Norwegian Petroleum Directorate et al., 2008; Power from shore to oil and gas platforms, Zero, 2011.

b. Technological development and greenhouse gas emissions from the petroleum industry towards 2030 and a low emissions society by 2050, DNV, 2015.

Investing in floating wind turbines

Floating offshore wind power presents the possibility of achieving major reductions in greenhouse gas emissions from fossil fuel production while creating a market opportunity to develop new renewable solutions.

Norway's greenhouse gas emissions have been relatively unchanged since 1990. The country has had major emissions reductions from heating and conventional land-based industry. Proportionately large increases in emissions, primarily from the petroleum industry, have meant that overall emissions have been fairly stable.

The combination of increased emissions in the oil and gas industry together with reductions in other sectors have meant an increase in the industry's share of the Norwegian emissions. Fulfilment of Norway's climate goals (40 percent reduction in greenhouse gas emissions by 2030, and more than 80 percent reduction by 2050) is increasingly dependent on cuts in the petroleum industry.

The climate effect of electrification

In 2017, the oil industry was responsible for approximately 15 million tons of greenhouse gases. The potential for emissions reductions from electrification of the NCS, is estimated to be 3–7 million tons. Since wind turbines are dependent on external conditions, total climate reductions from the connection of up to 1 GW of offshore wind power by 2030 is estimated at approximately. 1–3 million tons per year. In such a case, this is equivalent to roughly 5 percent of Norway's total emissions. Potential reductions depend on cost, the type of solution, and to what extent this is connected with common networks in hubs and onshore.

Expansion of offshore grid interconnections between platforms enables a greater degree of flexibility and higher proportion of wind power and thereby greater emissions reductions.

The climate effect of more renewable energy

The countries around the North Sea still have a very high level of fossil fuel-based power generation. Offshore wind power connected directly to the European power system or through Norway can contribute to significant climate improvements. In simplified terms, an average CO_2 factor of approx. 500 gram CO_2/KWh can be used as a basis for power from gas-turbine power plants, and just over 1,000 grams of CO_2/KWh for coal[1]. 1 TWh of coal power therefore means emissions of approx. 1 million tons of CO_2 and half a million tons from a gas power plant. 50 TWh of coal power is then roughly equivalent to total Norwegian greenhouse gas emissions.

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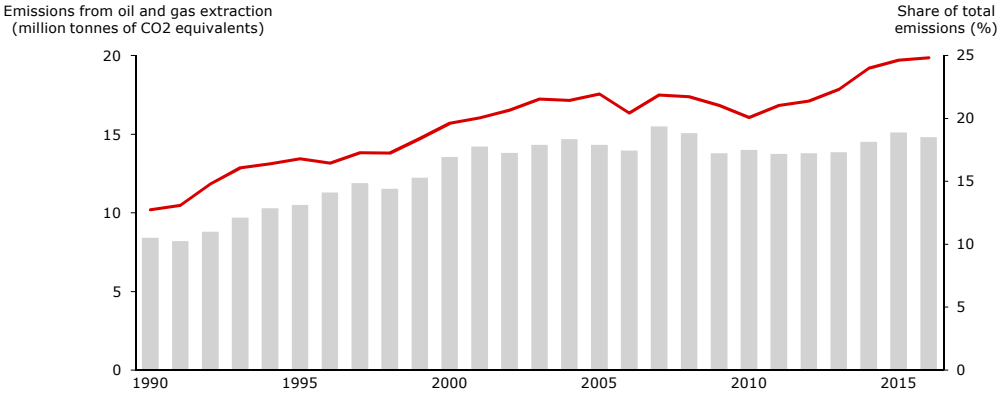
Source: SSB



The power grid must always remain adjustable since demand varies. When more renewable non-controllable power is generated, flexible coal and gas production are reduced proportionately. In the diagram showing German power generation per hour for one week, we can see how coal and gas production fluctuate in pace with renewables production and consumption. A power connection to Norway will therefore result in significant climate reductions.

Figures from North Connect show that the climate benefit of the planned interconnection between Norway and the United Kingdom is approximately 5 million tons of CO_2 per year, decreasing to 1 million tons around 2040.

Increased use of wind power requires an expansion of grids so that the power can be moved to where it is needed. Geographic distribution of generation means that we can make use of different weather systems, as well as the fact that wind systems come in over land at different times and in different places. This is where Norwegian offshore wind farms present major advantages.

- Norwegian offshore wind farms can be placed in other weather systems and generate wind power at different times compared to neighbouring countries
- Norwegian offshore wind will have a high capacity factor and therefore delivers power for more hours per day, with less need for gas or coal to step in when the wind is not blowing. German onshore wind turbines have a total utilization rate of 20 percent, meaning that there is low or no production over most of the year. Offshore wind power has a higher utilization rate. The test turbine “Hywind” doubled this capacity at 40 percent and new installations can be expected to have even higher rates.

The climate benefits of Norwegian offshore wind power can be very high if it is delivered to Europe. At the same time, Norway has a significant “battery capacity” through adjustable use of Norwegian hydropower. Expansion of more offshore wind power frees up production capacity in regulated and expanded regulatable hydropower. At the same time, studies from Cedren show that Norway can increase capacity in the hydropower system by 60 percent simply by using existing reservoirs without significant natural intervention[2].

1. https://www.nve.no/reguleringsmyndigheten-for-energi-rme-marked-og-monopol/varedeklarasjon/nasjonal-varedeklarasjon-2017/
2. https://www.sintef.no/siste-nytt/frykten-for-nye-utenlandskabler-er-grunnlos/

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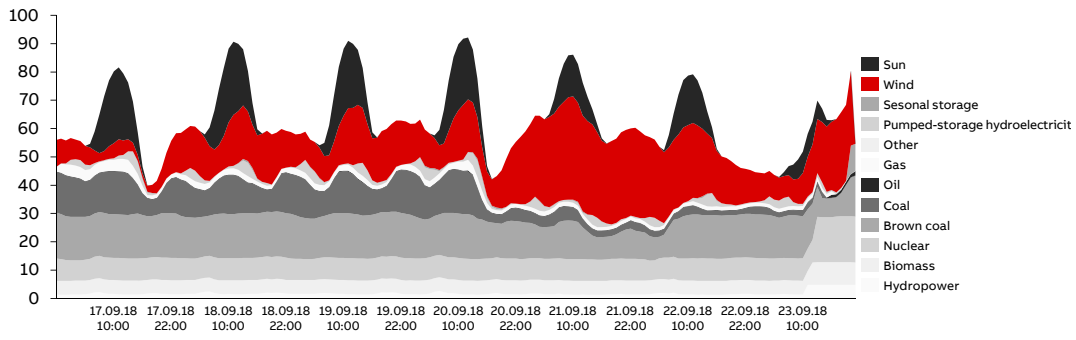
German power generation over one week in September 2018. Coal and gas balance the power system. Note how consumption and production fluctuate between night and day. Source: www.energy-charts.de, Fraunhofer IFE



Commercializing and preparing Norwegian business for a world market

Innovation in solar, onshore wind and fixed-bottom offshore wind power technologies trigger major cost reductions. New projects can see a decrease of nearly half of the original costs accumulated in the previous year. This takes place in interplay between expansion, customers and technology providers consisting of many different factors, such as incremental improvements, new methods, and reduced financial risk. This demands the establishment of a home arena where it is possible to market the technology, certify providers, and drive down costs. Partial electrification of the NCS with floating wind turbines and opening the proposed areas for offshore wind farms is the first step in making Norway a major supplier of offshore wind power.

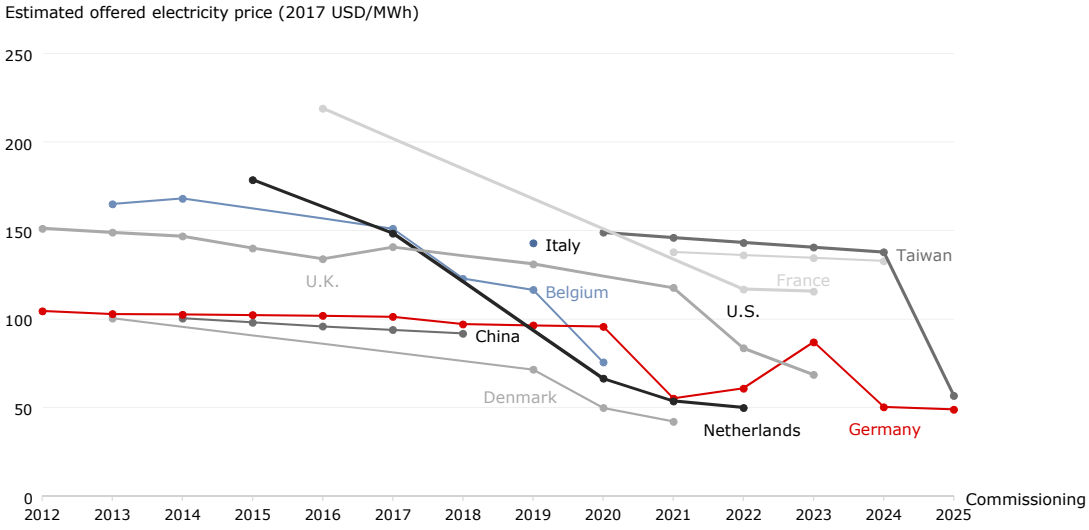
Floating offshore wind power is a major market opportunity for Norwegian business. Figures from 2016 show that the Norwegian industry already exports around 500.000 USD of offshore wind technology and solutions. This is more than all other renewable energy technology and service exports combined, including hydropower[3]. In a report from 2017, Norwea[4] and others estimate that the market will grow to 50 billion USD by 2030, with a recommended goal for a Norwegian market share of ten percent (5 billion USD) by 2030.

Norwegian maritime and offshore industries possess the expertise, capacity for innovation and drive to succeed in the world class. Once costs come down, floating offshore wind power has the potential to become a large world market where Norwegian business can deliver solutions, components, service, and competence. In contrast to onshore wind or fixed-bottom offshore wind power, no states have gone ahead and created sufficient demand for the industry to have trained sufficiently. Technological development, learning, and cost reduction do not advance alone in a laboratory, but rather through cooperation between producer and user.

Early in 2018, bids were submitted for 1,610 MW in Germany's second offshore wind power auction. The weighted average on the winning bids was 46.6 EUR/MW or equivalent to less than 0.06 USD per kWh. We also see that the price level in Denmark and the Netherlands is already approaching these levels now. This development has to be triggered for floating wind power.

As with all other major infrastructure investments, positive interactions between private and public sector operators are a must. In order to position Norway as a global leader in energy transformation and floating offshore wind power, a clear and quantified vision for Norwegian offshore wind-based generation in 2030 is needed in order to:

- Establish a new major export opportunity for Norwegian business by first establishing a solid



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Source: Bloomberg New Energy Finance

domestic market for the Norwegian supplier industry in offshore wind power.
- Demonstrate global social responsibility by offering an abundant but clean and cost-effective power to the Norwegian and European market, based on Norwegian wind resources in addition to hydropower.
- Establish effective political and administrative processes for expansion of offshore wind power and power transmission.
- Close cooperation with neighbouring countries, including joint expansion of production and infrastructure.
- Supplement Norwegian hydropower with wind, so that Norwegian hydropower reserves can be better used in cooperation with European energy supply.

Offshore wind power around the world

Over the course of 2018, we will get up to more than 24,000 MW of installed capacity of offshore wind on a global basis, with the majority of this in Europe[5]. Significant growth is expected over the coming years and the Norwegian Energy Partners (Norwep) report estimates that over the course of 2023 we will have more than 61,000 MW of installed capacity. Total investments between now and 2023 are estimated at 160 billion USD globally. The market opportunities for Norway are therefore good, and a goal of 5 billion USD by 2030 does not appear unrealistic. In comparison, we exported 9,4 billion USD of seafood in 2017 and 37,8 billion USD in equipment for the offshore petroleum industry.

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The Norwep report estimates that over the course of 2023 we will have more than 61,000 MW of installed capacity.

Norway currently has 0 MW of installed offshore wind power capacity and can reach 88 MW by 2023 if the Hywind Tampen is created. France has a similar starting point of 2 MW of installed capacity as of 2018, but they have entirely different ambitions for the future: By 2023, it is estimated that they can reach up to 2,300 MW of offshore wind power based on their existing project portfolio.

Over the course of 2018, Great Britain will reach 8,600 MW of installed capacity, more than any other country. They are also making targeted investments in building up their own offshore wind industry, and plan to spend 60 billion USD on auctions starting in 2019, in addition to working with the industry to achieve 10 GW of wind power between 2020 and 2030[6].

3. "Havvind - Et nytt norsk industrieventyr" (2017) - rapport fra Norwea, Norsk Industri, Rederiforbundet og Eksportkreditt
4. "Havvind - Et nytt norsk industrieventyr" (2017) side 11
5. Annual Global Offshore Wind Market Report (2018) - Norwegian Energy Partners (Norwep) med flere
6. Clean Growth Strategy - oktober 2017. https://www.gov.uk/government/publications/clean-growth-strategy

The road ahead

There is a need to introduce subsidies once the first demo projects are in place, as these are hardly of sufficient scope to contribute to such a large price drop. Floating wind turbines will become competitive against natural gas on oil platforms and later able to participate in the onshore power market. An auction-based arrangement is presumably the most suitable to trigger a rollout of floating wind power as an offshore energy solution to the fossil fuel industry.

Changing framework conditions can be used in addition to,-or together with-subsidy arrangements to achieve the same objectives. Increase in CO_2 tax, or decrease in CO_2 emissions per unit generated can have the same effect and will also incentivize other technologies. This is similar to the British "Carbon Price Floor" arrangement. High quota price can help, but this is set outside the control of Norwegian authorities.

Laws and regulations
Renewable energy production is regulated by the Energy Act and by the Offshore Energy Act. The difference goes to the bottom line. Connected petroleum installations are covered by the Petroleum Act with related regulations. Equinor's "Hywind Tampen" project is subject to this act. No statues have yet been developed for the Offshore Energy Act, and the act has yet to be implemented. Appropriate statutes, standards, etc. must therefore be developed. Since there has been extensive construction of offshore wind power around the North Sea, standards and regulation are in place in other countries.

The Offshore Energy Act has seen limited application since its induction in 2010. The right to exploit renewable energy resources offshore belongs to the state and it is not possible to construct, own, or operate without concession from the Ministry. Establishment of renewable energy production offshore can only happen once an impact assessment has been carried out and after the state has opened specific areas to applications for concession. Operators are not able to stake out areas and then seek concession as is done on land.

Framework conditions and regulations
There is currently no subsidy plan or other form of incentive that can help ensure the expansion of floating and fixed-bottom offshore wind power turbines on a large scale. This contributes to the necessary cost reductions, enabling the solution to become competitive in its own right.

Electricity certificates
Offshore wind is covered by electricity certificates, however new installations can only get these certificates up until 2021. It is therefore unlikely to expect that projects falling under this arrangement will be expanded. The price drop on wind power in Norway and surrounding countries means that most likely there will not be any need for a new subsidy arrangement for onshore wind power after 2021. The government and Parliament have warned that the electricity certificates will not be replaced with another arrangement once concluded.

Enova
Floating offshore wind power is eligible for Enova subsidy, but only for individual innovation projects. Enova's program for full-scale innovative energy and climate technology is otherwise well-suited to trigger a few projects where floating offshore wind power reduces greenhouse emissions in the oil and gas industry. Requirements for this arrangement include the following:

- New solutions generate energy
- There is a significant environmental improvement
- The project has a clear technological and financial risk

This type of arrangement is designed to demonstrate new technologies and solutions. It is not a rights-based subsidy plan. In practice, this means that Enova is unable to provide recurrent, ongoing support for the rollout of floating offshore wind power.

Opening of areas

A process to open areas has been underway for a long time. In a strategic impact assessment in 2012/2013, Norges vassdrags- og energidirektorat (NVE) pointed out that the Southern North Sea I or II and Utsira Nord stood out. NVE validated this in 2018 and recommends these for opening. It is unclear when these areas may be opened.

The Offshore Energy Act opens the way for establishment of offshore power without impact assessment and area opening. In the proposition from the Odelsting (the larger of the two divisions of Norwegian Parliament), the Ministry writes the following about Section 2.2, "Paragraph four gives the Ministry the authority to grant exceptions to rules on opening areas in special cases. The margin for exception is narrow. This may be the case for applications to limit the pilot project to a defined timeline or similar, or for smaller plants that are power plants for petroleum installations. One cannot assume that applications for large production plants will be taken up for review."

It is somewhat unclear what the Ministry means with "smaller plants that are power plants for petroleum installations" and "large production plants." In everyday language, hydropower that is less than 10 MW is referred to as "small power," but there is no definition of "large" production plants or "smaller plants." The law was designed to allow for the opening of larger wind farms. Today, these are typically at 200 to 600 MW. One should therefore assume that "large production plants" are wind farms in the hundred megawatt class, and that "smaller plants that are power plants for petroleum installations" are plants that are smaller than this, but typically larger than small power. This is consistent with the power demands on petroleum installations, which usually are up towards 100 MW. For reference, Hywind Tampen is 90 MW.

Such an interpretation with a certain practical adjustment is in line with the preamble to the proposition where the Ministry writes that, "the draft legislation therefore confirms the central principles, and more detailed regulations will be drawn up once appropriate. This approach won wide support in the round of hearings."

Expedient crafting of the statues in conjunction with creation of the first installations is presumably necessary if expansion is not to be stopped. By setting clear regulatory objectives regarding offshore power on the NCS and through a combination of existing and new methods, we can achieve major climate reductions, a significant business opportunity for Norway, and contribute to necessary technological development.

This document was developed by ABB and ZERO in fall 2018.

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ZERO is an independent, non-profit environmental foundation that believes climate to be the most critical environmental concern and is working to develop zero-emissions solutions. The foundation aims to steer investments away from solutions that produce emissions. Our intent is to ensure practical transition at the greatest possible pace from climate threatening operations to emissions-free solutions, otherwise known as the green shift.
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ABB AS - main office
Bergerveien 12
Postbox 94
N-1375 Billingstad
Norway
Contact center: +47 22 87 20 00
Email: contact.center@no.abb.com
abb.no

ZERO
Youngstorget 1
N-0181 Oslo
Norway
Tel: +47 2 29 62 00
Email: zero@zero.no

zero.no