Nordic Energy Research

Accommodating Biodiversity in Nordic Offshore Wind Projects

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Contents

Foreword

The green transition needs to be truly sustainable. While scaling up renewable energy generation, we must simultaneously ensure minimal environmental impact, or even achieve a net-positive impact, via active measures to protect and enhance biodiversity.

In the Nordic region, the North and Baltic Seas have tremendous wind resources to support the planned twentyfold increase in installed capacity of European offshore wind power. However, this will put pressure on natural resources and create new challenges for spatial planning.

Offshore wind projects, from design to decommissioning, must accommodate the environment and other uses of the sea. Large-scale deployment of renewable energy can take place in balance with nature if we do it right. Here, Nordic co-operation can add value. Large offshore wind farms are already operating in the region, and new projects are being announced. As the industry grows, stakeholders are learning to gather the knowledge needed for sound strategic planning, to mitigate cumulative environmental impacts.

These ambitions go hand-in-hand with the Nordic vision of becoming the most integrated and sustainable region in the world. By leveraging our collaboration frameworks, offshore experience, and trust in authorities, we can explore new processes to support decisions.

This report draws on experience from the Nordic region and its neighbourhood, to explore how offshore wind power projects can accommodate biodiversity. I hope the examples herein will inform regulators, developers, and the public, with a view to increase the share of renewable energy in the Nordic energy system, while ensuring that biodiversity is conserved for the future.

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Stakeholder input and review of the report
This report is the result of input from numerous specialists representing offshore wind operators (Equinor, Vattenfall, Parkwind and Ørsted), manufacturers (Vestas), regulators (The Norwegian Environment Agency, The Norwegian Institute of Marine Research, The Danish Energy Agency, NatureScot), scientific institutions (The Norwegian Institute for Nature Research, The Royal Belgian Institute of Natural Sciences, The Rich North Sea Programme) and NGOs (WWF Norway, The Norwegian Fishermen's Association). A review of the report was completed by Rachel Asante-Owusu at The International Union for Conservation of Nature (IUCN).

The individuals and organizations that contributed to this study are not responsible for any opinions or judgements contained herein.

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Executive summary

This report recommends actions to accommodate biodiversity and improve stakeholder engagement for future offshore wind farm (OWF) development in the Nordics. Examples of good practices are illustrated in five case studies.

The analysis is based on a review of authoritative literature and interviews with stakeholders representing offshore wind operators, manufacturers, regulators, scientific institutions, and NGOs.

Recommendations

- Leverage existing frameworks for collaboration across the Nordic region and neighbouring countries for data collection and cumulative impact assessments.
- Initiate Nordic collaboration for marine spatial planning at sea basin scales to ensure minimal conflict with environmental and other sea users' interests.
- Explore potentials for sharing experience on practices for stakeholder engagement in wind energy development, across borders and industries in the Nordics.

OWF expansion in Nordic countries towards 2050

Denmark has the most experience with wind energy among the Nordic countries and is perceived as a model and pioneer in the area. Fixed foundation projects and energy islands are in focus. Denmark's current connected capacity is 1,699 MW, and the predicted connected capacity in 2050 is 36 GW.

Norway has just started the process of developing OWFs by opening the two first areas for licensing, and by approving plans for the development of Hywind Tampen. Due to deep waters in the North Sea, there has been an emphasis on developing floating wind. Norway has extensive offshore experience from the Oil and Gas industry to build on for OWF projects. Current connected capacity is 6 MW, and the predicted connected capacity in 2050 is 30 GW.

Sweden has long experience with wind energy. Currently, there are four active and operative OWFs in Sweden, four projects that have been authorised for development, and 30 projects in the planning phase. Fixed foundation-projects are most relevant in Swedish waters. Sweden's current connected capacity is 192 MW, and the predicted connected capacity in 2050 is 30 GW.

Finland also has long experience with renewable energy and good conditions for OWFs. Currently, there are two active OWFs and nine more installations being planned. Finland's current connected capacity is 71 MW, and the predicted connected capacity in 2050 is 15 GW.

There is less focus on OWF development in Iceland and the Faroe Islands and predicted capacity in 2050 is not known. Currently, Iceland has two active onshore wind turbines with a connected capacity of 1 MW each, and no OWFs. In the Faroe Islands, the municipal power producer and distributer is planning a fixed foundation OWF with a capacity of 150 MW.

Key challenges and opportunities

Key challenges related to the planned expansion of OWFs in the Nordics are: additional pressure on ecosystems; lack of data on ecosystems and impacts; conflict for space (e.g. fisheries); complex stakeholder engagement processes; a need for technology development (especially for floating wind); and grid connectivity.

Key opportunities related to the planned expansion of OWFs in the Nordics are: an increasing knowledge base on biodiversity impacts; opportunities for coexistence; ecosystem restoration and enhancement; possibilities to leverage existing collaboration frameworks; significant OWF and offshore experience; and high trust in authorities.

Success factors

- **Strategic planning in the opening process.**
  Case 1: The Danish way of opening areas for offshore wind; and in the project phase. Case 2: Avoidance by site characterisation in the Hywind Scotland Pilot Park project.
- **Coordinated collection and sharing of environmental data.**
  Case 3: Coordinated environmental monitoring: examples from Belgium and Norway.
- **Understanding cumulative impacts.**
  Case 4: Research on cumulative effects: "Cumulative Effects Framework for Key Ecological Receptors" (Scotland) and MARCIS (2021–2025) (Norway).
- **Managing underwater noise.**
  Case 5: General evaluation of bubble curtains as a sound mitigation measure.


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Chapter 1

Background

The role of offshore wind energy in the energy transition
Development of OWFs, both fixed and floating, will be a key factor if we are to reach future energy demands and climate goals in a cost-effective way. To reach climate neutrality by 2050, the European Commission anticipates that there will be a need for a twentyfold increase in Europe's OWF capacity (European Commission, 2020b). The Nordic region will play a key role, as it is estimated that the North Sea can supply around 200 GW by 2050 and the Baltic Sea around 80 GW (Wind Europe, 2019).

Developing new energy sources often conflicts with other environmental values. The European Green Deal[1] communication underscores that scaling up OWF development must be compatible with the EU Biodiversity Strategy. This requires that the transition to renewable energy should be done with minimal harm to the environment and contribute to nature conservation (European Commission, 2020a).

Offshore wind energy and biodiversity
Biodiversity is under increasing pressure. Last year's report from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019) states that human activities and natural trends have converged to severely damage the natural environment. The report documents that more than one million species (one out of four species) are at risk of extinction because of human activities. The report also concludes that the loss of biodiversity aggravates climate change, and that climate change intensifies biodiversity loss.

1 The European Green Deal is the Commission's commitment to tackle climate change and environment-related challenges and a tool to implement the United Nations' 2030 sustainable development goals (SDGs).

Although climate and biodiversity are interconnected, these topics are often discussed separately, both in politics and in research. However, this summer the Intergovernmental Panel on Climate Change (IPCC) and the IPBES published a report highlighting the links between biodiversity and climate, and their joint relationships with human activities and wellbeing (Pörtner, 2021). One of the main conclusions of the report is that accommodating biodiversity has positive effects for the climate.

Wind energy can help preserve biodiversity by reducing GHG emissions and by producing a surplus of energy over its life cycle. Other environmental benefits of wind energy are that it requires no water for power generation and that it causes little air, soil or water pollution during operation, compared to other carbon-based energy sources. Properly planned and designed projects can also have a direct positive effect on nature conservation and restoration in a local perspective. Poorly sited or poorly designed wind farms can, however, have negative direct, indirect or cumulative effects on biodiversity.

The large up-scaling of OWF development will translate into extensive deployment of activities related to construction, operation and decommissioning, which could potentially cause important cumulative impacts that will have to be taken into account when considering the impact of OWFs on biodiversity.

In this report, we discuss how new OWF projects in the Nordic countries can avoid, mitigate or compensate for negative biodiversity impacts and also how OWF projects can enrich biodiversity. The focus is on offshore-related activities in OWF projects. The content of the report is based on review of authoritative literature and reports in combination with input from discussions with stakeholders representing operators (Equinor, Vattenfall, Parkwind and Ørsted), manufacturers (Vestas), regulators (The Norwegian Environment Agency, The Norwegian Institute of Marine Research, The Danish Energy Agency, NatureScot), Scientific institutions (The Norwegian Institute for Nature Research, The Royal Belgian Institute of Natural Sciences, The Rich North Sea Programme) and NGOs (WWF Norway, The Norwegian Fishermen's Association).

1.1 Aim of the study

The specific objectives of the study are:

1. To identify key elements and recommended actions to accommodate biodiversity and stakeholder engagement in OWF projects in the Nordic region.
2. To illustrates key elements of existing practices through case studies.

1.2 Contents of the report

The report contains:

- An overview of technical solutions for OWFs in general, as well as development plans, regulatory regimes and the natural environment in North Sea and the Baltic Sea.
- A description of relevant policy frameworks for accommodating biodiversity while expanding renewable energy sources, including a recommended hierarchy of mitigation measures.
- Case studies reflecting key challenges and opportunities to accommodate biodiversity in future OWF development in the Nordics.

Photo left: unsplash.com.
Photo right: National Renewable Energy Lab. OffShore Wind. License.

Chapter 2

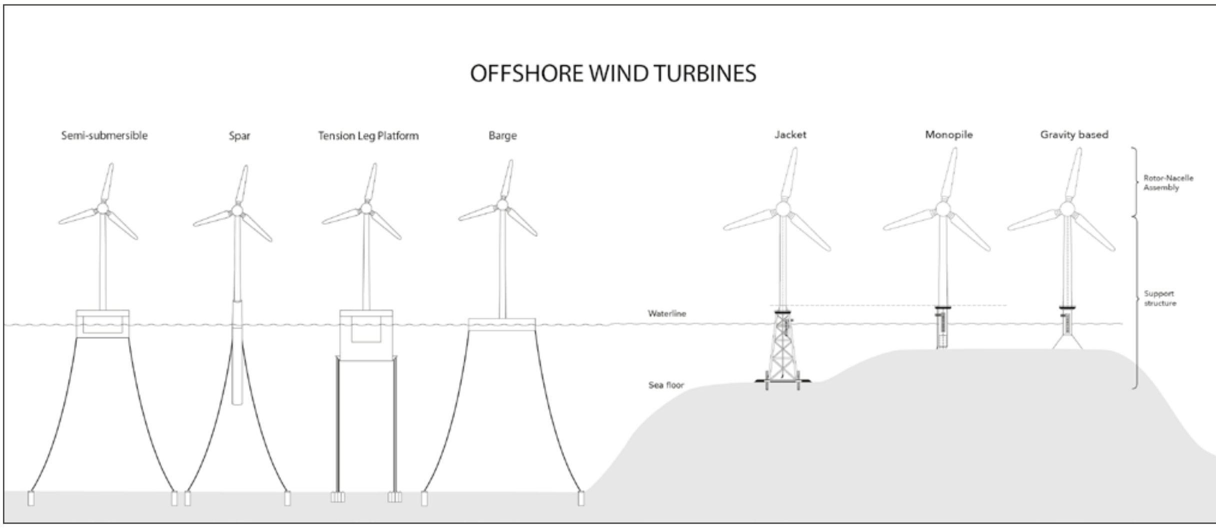
Concepts and status of OWF projects in the Nordic countries

2.1 Concepts and phases

Most OWF installations have a horizontal axis with a three-blade configuration and can either be bottom fixed or floating. A typical fixed OWF turbine structure comprises components both above water (nacelle, rotor, blades and tower) and below water (substructure, foundation and scour protection material). The foundations are typically made of steel substructures fixed to the seabed by driven piles or suction buckets. The steel structures can either be monopile or jacket substructures. Gravity-based substructures made from concrete and steel have also been used. Bottom-fixed turbines are usually installed in water depths up to 60 metres. In deeper waters, floating turbines are employed. Floaters are categorised in terms of how they achieve hydrostatic stability.

An advantage of floating wind turbines compared to bottom-fixed installations is that they give access to abundant wind resources over deep water and more ocean surface space. Floating installations are currently mainly limited by price. A recent study by DNV indicates that significant technological developments in floating wind within the next five years will entail reduced cost, improved scalability and increased applicability. The study indicates that floating wind will contribute 250 GW, two per cent of the world's electricity generation by 2050 (DNV, 2021).

Figure 1. Different types of fixed and floating wind turbines. Illustration by DNV.



OWF projects can be divided into the following phases:

- Site characterisation (e.g. baseline studies, studies of sediment stability)
- Construction (e.g. installing foundations, construction of monopiles, fixed and floating turbines)
- Operation (including maintenance)
- Repowering (upgrading turbines in an existing wind farm)
- Decommissioning (removing the wind farm and individual turbines).
- End of life (disposal of turbine blades)

All phases can have direct, indirect and cumulative impacts on biodiversity and ecosystem services. Impacts differ depending on the type of installation (floating or fixed) and to a large degree depend on the natural environment where the installation is located.

2.2 Status of OWF projects in the Nordic countries

The status of OWF projects (both fixed and floating) in the Nordics and neighbouring countries is shown in Figure 2. Bottom-fixed substructures are currently the most prevalent approach in the southern parts of the North Sea, in Kattegat and in the southern parts of the Baltic Sea. Only two floating OWFs are currently online (one for research purposes outside Karmøy in Norway and the Hywind Scotland project in Scotland) and two are under construction. In Europe, the UK is producing the most electricity from OWFs, with 11,021 MW from 2,355 turbines. By comparison Denmark is producing 2,308 MW, Sweden 192 MW, Finland 71 MW and Norway 2 MW (Wind Europe, 2021).

See figure 2 in Appendix. Status of OWF projects in the Nordics and neighbouring countries, based on bottom-fixed (upper map) and floating technology (Wind Europe, 2021).

2.3 Development plans and policy frameworks for OWF projects in the Nordic countries

The following subchapters supply a brief overview of OWF development plans in the different Nordic countries.

2.3.1 Denmark

Development plans

Denmark has a long tradition of utilising wind for power generation. Since the 1980s, the Danish government has had a proactive approach to the development of renewable energy. As a result, wind power started benefitting from a range of policies and reforms which helped accelerate development, including subsidies of up to 30 per cent of installation costs and refunds on Danish carbon tax (IRENA, 2013).

While support for renewable energy stagnated in the 2000s, political support for wind energy was reinvigorated following the 2009 United Nations Climate Change Conference (COP15) in Copenhagen. This led to the reform of the Promotion of Renewable Energy Act, which gave rise to OWF power in Denmark. OWF development in Denmark has made great strides over the last couple of years, aided by incentives from Danish government. As a result, OWF power represented about 18 per cent of the country's electricity in 2019 (Ifri, 2021). Between 1995 and 2019, 14 different OWFs were constructed in Denmark, with a total capacity of 1,699 MW.

See figure 3 in Appendix. Map of existing OWFs in Denmark (Danish Energy Agency, 2021).

Horns Rev 3.
Photo: Vattenfall

Denmark sees itself as both a model and a pioneer for green growth and presented its Climate Action Plan in May 2020 (DMF, 2020). Here, Denmark states that OWFs will be a key part of the government's investment policy.

This commitment can also be seen in the list of Denmark's existing OWFs:

- Tunø Knob (1995) 10 turbines, 5 MW
- Middelgrunden (2000) 20 turbines, 40 MW
- Horns Rev I (2002) 80 turbines, 160 MW
- Rønland (2003) 8 turbines, 17.2 MW
- Nysted (2003) 72 turbines, 165.6 MW
- Samsø (2003) 10 turbines, 23 MW
- Frederikshavn (2003) 3 turbines, 7.6 MW
- Horns Rev II (2009) 91 turbines, 209.3 MW
- Avedøre Holme (2009/10) 3 turbines, 10.8 MW
- Sprogø (2009) 7 turbines, 21 MW
- Rødsand II (2010) 90 turbines, 207 MW
- Anholt (2013) 111 turbines, 399.6 MW
- Nissum Bredning pilot turbines (2018) 4 turbines, 28 MW
- Horns Rev 3 (2019) 49 turbines; 400 MW

Kriegers Flak.
Photo: Vattenfall

Denmark also has a number OWFs under development or undergoing feasibility studies:

- Coastal offshore wind farms (Vesterhav Nord/Syd) 350 MW
- Kriegers Flak 600 MW
- Omø Syd 200–320 MW
- Jammerland Bugt 120–240 MW
- Mejl Flak 60–120 MW
- Lillebælt Syd
- Frederikshavn Offshore Wind Farm 21.6–72 MW
- Aflandshage 250 MW
- Nordre Flint 160 MW
- Thor Offshore Wind Farm 800–1,000 MW
- Kadet Banke Offshore Wind Farm 504–864 MW
- Paludan Flak 154–228 MW
- Treå Møllebugt 434–720 MW
- Hesselø Offshore Wind Farm 800–1,200 MW

As part of the Danish Climate Action Plan of 2020, a central strategy is to push towards shifting from individual OWFs to energy islands/hubs. As a result, the Danish Parliament has recently given the green light for a project aimed at creating the world's first artificial energy island, to be located in the middle of the North Sea (80 kilometres off the west coast of the Jutland peninsula). It will cover an area of approximately 120,000 square metres and, in the first phase of development, will be connected to about 200 OWF turbines for a capacity of 3 GW, a figure which is expected to reach 10 GW in the future (DEA, 2020).

Denmark is also planning a second, though smaller, (non-artificial) energy island in the Baltic Sea, on the Danish island of Bornholm. The island will serve as an OWF hub for a capacity of 2 GW and will potentially act as an interconnector between Germany and Denmark, following an agreement between the two countries' respective TSOs to investigate the benefits of building such an electricity connection.

Governance and policy frameworks

The Danish Energy Agency (DEA) is the competent authority for Danish onshore and offshore wind projects. In addition to calls for tenders and the approval of new projects, continuous work is being carried out on environmental impacts and future locations.

In Denmark, development of an OWF can happen through two different procedures: tender or application. In tenders, the Danish government is responsible for all aspects of project planning and design, while the construction and operation of the project is put to tender. In application processes, private developers submit applications containing the design and proposed location. Both alternatives result in the same type of permit.

In 1995, a spatial planning committee for OWFs was established and still exists. The committee is led by the DEA and consists of government authorities responsible for the environment, safety at sea and navigation, offshore resource extraction, visual interests and factors related to grid transmission. Furthermore, the committee comprises technical expertise in wind power, as well as in turbine, foundation and grid technologies. There is also emphasis on ensuring the planned and coordinated development of OWFs and the associated transmission grid.

OWF sites are regulated by the DEA in cooperation with the following other agencies:

- The Danish Environmental Protection Agency (DEPA)
- The Danish Maritime Authority (DMA)
- The Danish Working Environment Authority (DWEA)
- The Danish Safety Technology Authority (DSTA)
- The Danish Emergency Management Agency (DEMA)

Offshore wind development in Denmark is anchored in the Renewable Energy Act. The purpose of the Act is to promote energy production through the use of renewable energy sources in accordance with climatic, environmental and socio-economic considerations, in order to reduce dependence on fossil fuels, ensure security of supply and reduce emissions of CO_2 and other greenhouse gases. In particular, the Act aims to contribute to ensuring the fulfilment of national and international objectives of increasing the portion of energy produced through the use of renewable energy sources.

Furthermore, the Electric Supply Act ensures that the country's electricity supply is organised and implemented in accordance with considerations of security of supply, economy, environment and consumer protection. Within this objective, the Act ensures consumers access to cheap electricity and gives consumers influence over the management of the electricity sector's values. The Act also aims to promote sustainable energy use, including through energy savings and the use of cogeneration, renewable and environmentally friendly energy sources, in addition to ensuring the efficient use of economic resources and creating competition in electricity generation and trade markets.

The Act on Environmental Assessment of Plans and Programmes for Specific Projects ensures a high level of environmental protection and contributes to the integration of environmental considerations during the development of offshore wind projects. The Act ensures proper assessments and permits to promote sustainable development, by conducting environmental assessments of plans, programmes and projects that can have a significant impact on the environment.

2.3.2 Norway

Development plans

Norway has one of the world's longest coastlines and three different sea areas: the North Sea, the Norwegian Sea and the Barents Sea. The latter sea has an average depth of 230 metres, while the average depth of the other two is 90 metres. Due to the deep waters, there has been an emphasis on developing floating wind in Norway.

Norway's strategic national energy policies are important for the development of OWFs in Norwegian waters, as developing floating wind requires the development of new technologies before commercialisation. As a result, there have been extensive technological advances in the Norwegian OWF industry over the last couple of years.

On 12 June 2021, the Norwegian government opened the two first areas for OWFs: Utsira Nord and Sørlige Nordsjø II. This means that it is possible to apply for licence in these areas. The guidelines for the application process were published for public consultation in June 2021 (The Norwegian Ministry of Oil and Energy, 2021). The deadline for submitting comments was 20 August, and the announcement process for pre-qualification is expected to start in Q3/Q4 2021.

According to the Norwegian government, Utsira Nord is an area that is well suited for offshore floating wind. In addition, the area is quite large and represents possibilities for balancing other industries and interests, as well as allowing for energy production close to existing infrastructure. Sørlige Nordsjø II is located in the southern part of the North Sea, towards the Danish border (Figure 4), and the area is suitable for both floating and fixed-foundation OWF projects. The area is also well positioned to allow for exporting energy to central Europe. It is estimated that OWFs in these two areas could generate 4,500 MW of energy.

In addition to the development plans related to Utsira Nord and Sørlige Nordsjø II, the Ministry of Petroleum and Energy (MPE) has approved the plans for the development of Hywind Tampen. Hywind Tampen is planned as an 88 MW floating OWF installation intended to provide electricity to the Snorre and Gullfaks offshore oil and gas platforms. The project will be located approximately 140 kilometres off the Norwegian coast, in the Tampen area of the Norwegian part of the North Sea, between the Snorre and the Gullfaks fields. The project is considered an important milestone towards commercialisation of floating wind.

Hywind: The world's first full-scale floating wind turbine, assembled in the Åmøy Fjord near Stavanger.
Photo: Lars Christopher. CC BY 2.0 via Wikimedia Commons

Policy frameworks

Although the overall policy frameworks are in place, there is currently no established detailed regulatory framework for OWF projects in Norway. Hywind Tampen followed the model for oil and gas development projects, but MPE has now initiated a project to develop a detailed regulatory framework for OWFs. The framework will be based on the 2010 Offshore Energy Act, the Marine Energy Regulations and the white paper "Putting Energy to work – Long term value creation for Norwegian energy resources" (The Norwegian Government, 2021).

The Offshore Energy Act governs the utilisation of renewable energy resources at sea. The Act entered into force in 2010, with the aim of facilitating the utilisation of the offshore renewable resources on the Norwegian Continental Shelf (NCS). The MPE has the responsibility for the regulations under the Act, i.e. the licensing process and permits. The purpose of the Act is to ensure that the utilisation of resources and deployment of technology offshore are in accordance with societal needs and ambitions, accounting for environmental aspects, energy distribution needs and competing business interests.

The Offshore Energy Act applies to Norwegian sea territory outside the baseline and on the Norwegian Continental Shelf (NCS). The Act stipulates that production facilities cannot be built, owned or operated without a licence from the MPE and requires a regional impact assessment prior to opening an area for applications for licences. It also requires applicants to create a plan for a field-specific impact assessment as part of the licence application. The impact assessment must include assessments of the environmental and societal consequences of renewable energy production, such as consequences for other business interests. However, there are no detailed content requirements.

The Marine Energy Regulations specify rules for licence applications and state that the MPE is the licensing authority for OWFs and will also receive notices of development and applications. The Norwegian Water Resources and Energy Directorate (NVE) will support the MPE with technical advice in the licensing process and has the authority to approve the detailed plans.

The published suggested *Guidelines for licence applications* include further clarifications related to the licensing process, starting with the MPE dividing the opened areas into smaller project areas. A project area has a specified maximum installed effect and will be allocated to one prequalified operator. Prequalification is based on financial capacity and competence within the technological, environmental and safety aspects of OWF development projects. For areas suitable for fixed OWF projects (like Sørlig Nordsjø II), the allocation of areas will be through competitive bidding. The detailed rules for the bidding process have not yet been decided. For areas suitable for floating OWFs (like Utsira Nord), allocation will be based on a qualitative competition to favour projects contributing to technology development. The allocation gives the applicant the exclusive right to submit a plan for conducting an impact assessment in the area but does not guarantee a licence to operate.

Utsira Nord is located in an area off the coast of Haugesund in western Norway, known for having consistently strong winds.
Photo: Atle Grimsby. Hywind in green light. License.

See figure 4 in Appendix. Map of Utsira Nord and Sørlige Nordsjø II. (MPE).

"Putting Energy to work – Long term value creation for Norwegian energy resources" suggests that Statnett (the Norwegian power system operator) will be the system operator for connecting the offshore grid to Norway. The operators will be responsible for building and financing the power cable required for their project.

Other relevant agencies for renewable energy generation on the NCS: The Petroleum Safety Authority (PSA) is responsible for safety, the working environment and emergency response related to renewable energy generation on the NCS.

The Norwegian Coastal Administration (NCA) has been awarded the responsibility for safety zones and marking.

The Norwegian Maritime Authority (NMA) is the administrative and supervisory authority in matters of safety related to life and health, material values and the environment on vessels sailing under the Norwegian flag and foreign ships in Norwegian waters.

2.3.3 Sweden

Development plans

Around half of all electricity production in Sweden comes from renewable sources. Wind power accounted for about 12 per cent of Sweden's total electricity production in 2019, having increased considerably in recent years (SCB, 2020). Given that Sweden is aiming for a target of 100 per cent renewable electricity production by 2040, there is a significant need to increase renewable energy production in the country. The Energy Authority estimates that at least 100 to 120 TWh of new renewable electricity production will be needed in the lead-up to 2040 of which at least 100 TWh will come from wind power (Energimyndigheten, 2021).

With the favourable conditions for wind power in the Baltic Sea (over 90 GW), Sweden (which has the longest coastline of all the countries bordering the Baltic Sea), has major potential to exploit and utilise energy from wind: 12–25 GW (BSOWEDJI, 2020). In 2020, Svenska Kraftnät (State owned electricity transmission operator) signed a letter of intent together with other responsible grid operators in countries adjacent to the Baltic Sea. The ambition is to cooperate in establishing a joint sea-based transmission grid connected to future OWF development projects and other sea-based power generation in the Baltic Sea.

In October 2021, the Swedish government assigned the development of an offshore transmission grid to Svenska Kraftnät, to accommodate future OWF projects, thus considerably lowering the total cost of OWF projects for developers. The Swedish government considers a strategic expansion of the transmission grid a key to achieve their goals for future renewable energy production, as well as providing OWF developers and operators a predictable and transparent framework for grid connection. The Swedish government also announce that OWF projects developed with a connection to the new grid will be granted economic advantages (The Swedish Government, 2021).

The Swedish government is currently working on its electrification strategy, where OWFs are expected to be a central contributor. The strategy is set to be announced during the autumn of 2021. The OWFs that are being planned by developers are mainly situated around the central and southern half of the country, where the need for electricity is the greatest.

Plans for OWF development in Sweden are changing rapidly. A testament to this is shown in the number of applications for development plans submitted to Svenska Kraftnät. In 2020, Svenska Kraftnät received OWF applications equivalent to 40 GW. For 2021, 70 applications for OWFs are being processed, equivalent to 135 GW (The Swedish Government, 2021). Currently, there are four active and operative OWFs in Sweden (Clarksons, 2021):

- Vindpark Vanern 30 MW
- Bockstigen II – Repowered 3.3 MW
- Kårehamn 48 MW
- Lillegrund 110.4 MW

In addition, four OWF projects have been authorised for further development:

- Stenkalles Grund 100 MW
- Stora Middelgrund 864 MW
- Storgrundet 1,200 MW
- Kattegat 282 MW

There are currently 30 projects in planning stages in Sweden (Clarksons, 2021). Among these is the OWF project Skåne Havsvindpark, which recently (September 2021) submitted an environmental report and impact assessment for a 1.5 GW development project off Sweden's southern coast.

Policy frameworks

The Swedish Energy Agency functions as an expert authority for wind power. It also supports and facilitates the expansion of wind power in Sweden.

Wind power development in Sweden is primarily driven by operators' and developers' investment plans and is regulated by the permit process and affected by spatial planning. The electricity market has been deregulated since 1996. Important principles in the electricity market are that price signals should control the expansion of new production and that regulations that can disrupt the markets should be minimised. The operators and developers select locations for wind farm development, based on wind conditions, connection possibilities, the existing grid, and probability for obtaining a permit based on other interests around the site. The developer applies for a permit for the construction and operation of the wind farm and for grid connection. Electricity grid expansion is controlled on the basis of how the demand for electricity evolves, as well as the supply to the grid.

In Swedish maritime territory, OWF developers must have a permit for activities affecting the environment, as well as for activities at sea, in accordance with the Environmental Code in addition to the municipality's approval. Permits for offshore wind development are normally considered by the Land and Environmental Court. In addition to environmental permits, OWF developers must also have permits for surveying the seabed and establishing cables in the maritime territorial zone.

As a general rule, Sweden's Environmental Code requires permits for all water activities. Applications for permits for environmentally hazardous activities are normally submitted to the county administrative board.

Applications for water activities are normally considered by the Land and Environmental Court directly.

Construction of OWFs outside Sweden's territorial waters requires a permit in accordance with the Swedish Economic Zone Act. To develop OWFs outside Sweden's territorial waters, but in Sweden's economic zone, a government permit is required, in accordance with the Swedish Economic Zone Act.

2.3.4 Finland

Development plans
Currently, electricity produced by wind power covers about seven per cent of Finland's annual electricity consumption. At the end of 2019, there were 754 wind turbines in Finland, with a capacity of 2,284 MW. The National Energy and Climate Strategy for 2030, approved by the government on 24 November 2016, states that the use of renewable energy will be increased so that its share will rise to more than 50 per cent during the 2020s. The strategy also states that Finland will prepare to make extensive use of the country's wind power potential in spatial planning. The siting of wind turbines must take into account techno-economic factors, environmental values and other land use.

With its shallow waters and good wind conditions, Finland is considered to have very favourable conditions for producing OWF power.

Currently, there are two active OWFs in Finland, Ajos wind farm (26.4 MW) which consists of eight turbines developed on artificial islands, and Tahkoluoto wind farm (42 MW) which consists of ten gravity-based turbines.

In addition, there are nine OWF development projects under development and/or undergoing feasibility studies:

- Åland 6 GW
- Tornion 70 MW
- Sipyyn 400 MW
- Raahe-Pertunmatala 72 MW
- Inkoo-Raseporin 300 MW
- Korsnäs 1,400 MW
- Tahkoluoto 500 MW
- Suurhiekka 400 MW

Policy frameworks
The development of OWFs in Finland is subject to the same regulations as general construction projects, both at sea and on land. The construction of wind farms is to be based on spatial plans drafted in accordance with the Land Use and Building Act. This means that spatial plans define areas

that are fit for wind farm development. The defining of wind farm areas in spatial plans is currently a contentious topic in Finland.

Local spatial plans define direct criteria for wind development under the 2011 amendment to the Land Use and Building Act. Existing and pending regional spatial plans allow for significant additional development of wind farms.

Building permits are required for developing wind farms. Depending on the location, it may be necessary to satisfy specific criteria and conditions, and obtain other permits. These could include, but are not limited to, a permit pursuant to the Aviation Act, a water permit pursuant to the Water Act or an environmental permit pursuant to the Environmental Protection Act.

Permits required for OWF development vary greatly, much depending on the location. In addition, locations in Finnish territorial waters and economic zone are treated differently when it comes to required permits.

2.3.5 Faroe Islands

Power production and distribution in the Faroe Islands is controlled by the inter-municipal community SEV, owned by the municipalities in the Faroe Islands.

Today there are no operational OWFs in the Faroe Islands. However, there are several onshore wind farms. Approximately 10 per cent, or 53 GWh, of the energy generated by SEV came from wind power in 2019 (SEV, 2021).

Due to the uneven weather conditions in the Faroe Islands, wind power is considered a fluctuating and unsteady source of energy, which must be coordinated with a battery system and other steadier sources, like hydropower. The challenge in the Faroe Islands is especially great because the country is an isolated island community and reserve power sources must be available in case wind turbines breakdown, etc. Hence, there is an emphasis on developing other, more stable green energy sources like hydropower, solar and tidal power.

Still, there is one OWF project in the development phase in the Faroe Islands. Recently, SEV has revealed plans to build an OWF near the Faroese capital Tórshavn. The wind farm will be a joint venture between SEV and various businesses and investors. The 96–120 MW OWF will replace at least five onshore wind farms that have been planned as part of the green path towards 100 per cent sustainable electricity generation by 2030.

2.3.6 Iceland

Historically, electricity generation from wind in Iceland has been limited to miniature turbines used off-grid at farms and cottages. In 2012, Landsvirkjun, the National Power Company of Iceland, established two research turbines, with a capacity of 900 kW each, in the Icelandic highlands at Búrfell, to monitor how wind turbines respond to the Icelandic climate. The research project was considered promising and Landsvirkjun is currently developing and finalising the plans for a 200 MW wind farm in the same areas.

The Icelandic Meteorological Office has stated that wind should be seriously considered as a source of electricity in Iceland. Due to onshore wind conditions being so favourable, and promising results from the R&D project at Búrfell, as well as an abundance of low-cost geothermal and hydropower options, OWF development has yet to be prioritised by the Icelandic government.

The HIP Atlantic Project, a joint venture project between Independent Power Corporation and Hecate Energy, plans for a 10 GW fixed-and-floating turbine OWFs in Icelandic waters, with export to the UK. The project aims to apply for entry points to import wind power directly to UK grid operator National Grid. The developer is currently working with the government in Iceland to lease seabed.


Photos: unsplash.com

Chapter 3

Nordic marine ecosystems

Most of the planned expansion of OWFs in the Nordics will happen in the North Sea and the Baltic Sea. A high-level description of the physical and biological environments in the two sea basins is provided below. The marine ecosystems surrounding the Faroes Islands and Iceland have similarities with the northern part of the North Sea.

3.1 The North Sea

The North Sea is a large, semi-enclosed sea, formed by flooding in the Holocene period. The North Sea is limited by the coastlines of England, Scotland, Norway, Sweden, Denmark, Germany, the Netherlands, Belgium, and France.

Atlantic water enters the North Sea mainly from the north. The topography produces a counterclockwise circulation. Water entering from the Channel moves eastward along the Belgian/Dutch coast. In the Skagerrak, the North Sea water mixes with less saline water from the Baltic Sea and is transported north along the west cost of Norway. Surface water temperature varies between 0 and 20 °C, depending on the season and the part of the sea, with less variation in the north.

The seabed is predominantly sandy, but muddy in deeper parts and in southern coastal areas with extensive river influence. The coastlines display a large variety of habitats. In Scotland and Norway, the coastlines are mountainous and rocky, often dissected by deep fjords. The Norwegian and Swedish mainland is sheltered from the open ocean by a more or less continuous archipelago. The coasts of northern England and Scotland have a variety of cliffs, pebble beaches, estuaries, sand, and mud flats. From the Channel to the west coast of Denmark, sandy beaches and dunes prevail, with numerous estuaries and the tidal inlets and islands of the Wadden Sea. The Wadden Sea extends from the Netherlands to Denmark and is an ecologically important area with extensive mud flats, sheltered by barrier islands.

Most sources of nutrients are linked to anthropogenic activities. Major rivers, such as the Rhine, Elbe, Weser, Ems, and Thames, discharge into the southern part of the sea. Nitrogen in rivers originates mainly from agricultural soil fertilisation. Phosphorus is primarily linked to urban wastewater and soil erosion.

Biodiversity

Most of the seabed in the North Sea hosts soft-bottom communities, apart from the land margins of Norway and the United Kingdom where rocky shores dominate. Rocky shores have the most developed macroalgal communities in the region, with vegetation down to approximately 15 metres in the southern part and 30 metres in the northern part of the sea (OSPAR, 2000). Kelp forests are widespread in rocky sublittoral areas in the northern part of the region, and many species of flora and fauna find shelter, food, and surfaces for attachment on the kelp and the surrounding rocky substrate. Different communities develop, depending on factors such as exposure, turbidity, grazing pressure, and substrate type. Different species directories list about 820 macroalgal species for the British Isles and the surrounding seas, 370 for the Norwegian coastline, 325 for the northern part of Kattegat, 274 for Helgoland, and 230 for the Netherlands (Bartsch, 2000). Benthic microalgae are a primary source of nutrition in shallow waters for larger grazers and fish, like the mullet (OSPAR, 2000). These algae, suspended by wave action, constitute up to 90 per cent of the primary production in these waters.

Approximately 230 species of fish inhabit the North Sea. Species diversity is considered low in the shallow southern North Sea and eastern Channel, and increases westwards (Rogers et al,1998). Species diversity is also generally higher inshore (Greenstreet and Hall, 1996), as there are more varied sediment types and spatial niches. Most of the variability of the fish stocks is due to variation in egg and larval survival. The North Sea is one of the world's most productive areas for fish and a large number of commercially important species are caught in this area. The total biomass of all fish in the North Sea is estimated at approximately 10 million tonnes. The total landings of different fish species in 2018 amounted to roughly 2 million tonnes (ICES, 2020b).

Most of the stocks of the commercial fish species in the North Sea are considered to be threatened, where about 30–40 per cent of the biomass of these species is caught every year (EEA, 2017).

Common guillemots (Uria aalge) are numerous and especially important in the North Sea, and have shown locally differing reactions to OWFs. Photos: scanpix.dk

The bird populations of the North Sea area are of global importance. There are 31 species of seabirds that breed along the coasts, and major seabird colonies live along the rocky coasts in the northern part of the North Sea. Some 10 million seabirds are present at most times of the year, but migrations and seasonal shifts are pronounced, and none of the species is endemic. Many shorebirds, such as waders and ducks, feed in inter-tidal areas along the coast. The Wadden Sea is of particular importance for both breeding and migratory populations, with 6 to 12 million birds of more than 50 different species present every year (OSPAR, 2000).

The overall seabird population showed an increasing trend until the 2000s, after which there has been a decline in the numbers of breeding seabirds. This is also true for migrating seabirds, possibly due to milder winters, meaning that these migrants can remain in waters closer to their breeding grounds, for example in the Norwegian Sea or the Barents Sea (ICES, 2020b).

The breeding abundance of more than a quarter of the seabird species assessed by OSPAR has been below the baseline set in 1992, indicating that the populations are not healthy (OSPAR, 2017). There is, however, a difference in species with different feeding and hunting strategies, suggesting that food availability and ecosystem-specific changes are reasons for changes in populations – possibly initiated by past and present fisheries in combination with climate change (OSPAR, 2017). In contrast, non-breeding populations in the Greater North Sea are doing much better and are considered healthy, with 75 per cent more of species meeting OSPAR's assessment values since 1993.

Three species of seal and 16 species of whale are more or less regularly observed in the North Sea (OSPAR, 2000). The grey seal (*Halichoerus grypus*) and the harbour seal (*Phoca vitulina*) both breed in the area. The grey seal is most abundant in exposed locations in the north-west, while the harbour seal is more widespread, often found on mud and sand flats.

See figure 5 in Appendix. Greater North Sea ecoregion, showing exclusive economic zones, larger offshore Natura 2000 sites, and operational and authorised wind farms (ICES 2020b).

3.2 The Baltic Sea

The Baltic Sea is a relatively shallow inland sea in north-east Europe, bounded by the coastlines of Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, the Russian Federation, and Sweden. The catchment area is 1,650,000 km2, more than four times the area of the sea itself. Almost 80 million people live within the catchment area. The ecoregion has many islands and a long and diverse coastline, especially in the areas adjacent to the Nordic countries. The sea is characterised by strong temperature and salinity gradients, from relatively warmer and saline waters in the southwestern part to cold and almost freshwater in the northernmost parts. In addition, there is a strong, permanent vertical stratification for much of the Baltic Sea.

The shallow sounds between Sweden and Denmark provide limited water exchange with the North Sea. There is a clear salinity gradient from the almost oceanic conditions in the northern Kattegat to the nearly freshwater conditions in the northern Gulf of Bothnia. Most of the water input comes from rivers, with marked seasonal and long-term variability. The freshwater generates an outflowing low-salinity surface current towards the Skagerrak and North Sea, and an inflowing bottom current of higher salinity from the Skagerrak to the Baltic Sea. The tidal amplitude is small (8–18 cm) and it takes 25–35 years for all the water in the Baltic Sea to be replenished by water from the North Sea and beyond. Annual mean temperature increases gradually from north and east to south and west. The northern part of the Gulf of Bothnia (Bothnian Bay) and the coastal zone down to the Åland Sea and the inner parts of the Gulf of Finland and Gulf of Riga usually become completely ice-covered in January.

The Baltic is a young sea, formed after the last glaciation as the ice retreated some 10,000 years ago. Geological uplifting of land after the glaciation continues, especially in the northern part, where the uplift causes the coastline to retreat noticeably within a human generation.

OWF structures and areas between wind turbines can provide habitats for macroalgae and seaweed. Photo: unsplash.com

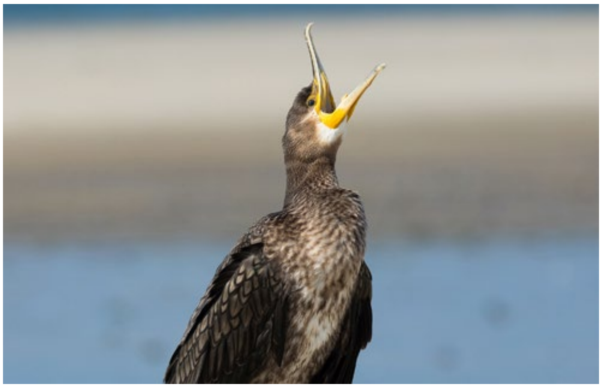
The Baltic Sea coast. Photo: unsplash.com

Biodiversity

Due to the geologically short time aspect and major changes, a very limited brackish water flora and fauna has developed. The Baltic Sea is therefore characterised by few species, but many individuals of each species. Another characteristic of the biology is that some freshwater and saltwater plants exist side by side, e.g. the freshwater plant common reed (*Phragmites australis*) and seaweeds such as marine wrack (*Fucus spp.*).

The number of marine macroalgae in the Baltic Sea decreases from more than 356 species in the Kattegat to fewer than 100 species in low-salinity waters (5–6 parts per thousand) in the Gulf of Bothnia. Most of the benthic vegetation in the Baltic Sea is of marine origin, but a small number of freshwater species have migrated into it, mainly into the Gulf of Bothnia. In the northern part of the Gulf of Bothnia, 32 species have been recorded, of which all but one is of freshwater origin (HELCOM, 2018).

There are about 100 fish species living in the Baltic, introduced into the region at different times in different ways. The distribution pattern of the various species reflects their original habitat and tolerance of salinity (ICES, 2020a). The ratio of the number of marine to freshwater species varies from north to south, as well as between coastal areas and open waters. Many species have their spawning and nursery grounds in the coastal zone, where archipelagos, river mouths and bays are especially important. The fish include marine species like cod (*Gadus morhua*), sprat (*Sprattus sprattus*) and herring (*Clupea harengus*), freshwater species like pike (*Esox lucius*) and perch (*Perca fluviatilis*), and species that live part of their lives in the sea and part in freshwater like Atlantic salmon (*Salmo salar*), sea trout (*Salmo trutta*) and European eel (*Anguilla anguilla*). Most species living in the Baltic Sea have adapted to the environment in various ways and differ from fish of the same species living in, for example, the North Sea or in freshwater.



Great cormorants (Phalacrocorax carbo) may be attracted to OWFs due to foraging and roosting opportunities, increasing their vulnerability to turbine collisions.
Photo: Frank Schulenburg. CC BY 2.0 via Wikimedia Commons

White-tailed eagles (Haliaeetus albicilla) are particularly vulnerable to collisions with OWF turbines off the Norwegian coast.
Photo: Jacob Spinks from England. CC BY 2.0 via Wikimedia Commons

Approximately nine million birds of some 57 species use the Baltic as a wintering area (HELCOM, 2018). The most important areas are the shallow lagoons, estuaries and sandy bottoms between Denmark, Germany and Poland, in the Gulf of Riga, and in the north-west area of Kattegat. Different species have shown different trends in breeding numbers over the past 30 years: nine species have declined, ten have increased, nine were stable, and the trend was uncertain in one species (ICES, 2020a). The greatest declines in breeding numbers were observed in common eider (Somateria molllissima) and great black-backed gull (*Larus marinus*). Three species that feed mainly on herring and sprat (common guillemot, razorbill, and Arctic tern) have increased in number over recent decades. White-tailed sea eagle (*Haliaeetus albicilla*) and great cormorant (*Phalacrocorax carbo*) have increased, following the cessation of hunting and the decline in persistent pollutants.

The Baltic Sea is also an important wintering area for many species, including the globally threatened long-tailed duck, velvet scoter (*Melanitta fusca*), and Steller's eider (*Polysticta stelleri*). These three species have been declining in number over the last 25 years, as have many other benthic-feeding species of seabirds.

The three species of seal found in the Baltic, the grey seal (*Halichoerus grypus*), the harbour (common) seal (*Phoca vitulina*) and the Baltic ringed seal (*Phoca hispida botnica*), live mainly in the archipelagos. The maximum number of grey seals counted in the Baltic in recent years is 6,000 individuals, which is considered a small number compared with pre-war conditions.

The Baltic Sea, and the countries surrounding it, are of critical importance to bat (Chiroptera) migration, especially Pipistrellus nathusii. More research is needed on the impact of OWFs on bat populations. Photo: unsplash.com

Otter (Lutra lutra) populations in the Baltic Sea fell dramatically in the 1990s, leaving them near threatened today. Otters are vulnerable to habitat loss in coastal areas, and their resting grounds may be affected by OWF development. Photo: unsplash.com

The harbour seal counts only a few hundred in the southern Baltic, and the situation is alarming.

The ringed seal counts about 3,000 individuals in the Gulf of Bothnia, but only a few hundred in the Gulfs of Finland and Riga where the populations are still particularly vulnerable (HELCOM, 2018).

The harbour porpoises (*Phocoena phocoena*) in the Baltic Sea are probably genetically specific and reproduce exclusively within this area. There is a possibility of total extinction in the Baltic Proper.

Otters (*Lutra lutra*) used to be common in the archipelagos, but numbers have fallen dramatically during the past few decades, probably due to polychlorinated biphenyl (PCB) poisoning (HELCOM, 2018). Otter recovery projects in adjacent countries are, however, beginning to succeed and may result in an increase in the Baltic population (European Commission, 2018).

Bats occur in a wide range of habitats, including forests and agricultural land, as well as along the coast of the Baltic Sea. Populations have been in serious decline, particularly in the second half of the twentieth century, and overall, bats remain vulnerable to habitat change and disturbance. From an ecological perspective, bats are good ecological indicators of the condition of ecosystems in and around the Baltic Sea. Bats are sensitive to even slight changes in their environment. Such responses can be useful in revealing habitat fragmentation, ecosystem stress or changing habitat use (Eurobats, 2018).

Harbour porpoises (Phocoena phocoena) may be displaced by OWFs, as they tend to leave the construction area due to habitat disturbances. Photo: scanpix.dk

Many OWFs in the Nordics are located in areas where Grey seals (Halichoerus grypus) and Harbour seals (Phoca vitulina) breed or forage. Noise and disturbance from the farms may affect seal populations.
Photo: unsplash.com

Many species and habitats in the Baltic Sea are in poor condition, according to recent assessments (HELCOM 2001, EEA 2008, ICES 2020b). This affects the functionality of the food web, reduces resilience and resistance against further environmental changes, and diminishes prospects for socioeconomic benefits, such as opportunities for fisheries and the development of renewable energy sources (ICES 2020B).

The following main influences are known to have a major effect on biological diversity in the Baltic Sea area (EEA 2008, ICES,2020):

- Eutrophication arising from overall loading of nutrients, fertilisation and sewage: the catchment area has extensive agriculture, and the southern areas are densely populated. Annual nutrient inputs continue to exceed regionally agreed goals, and concentrations remain relatively high in both water column and sediments. As examples of the consequences of this nutrient load, blue-green algal blooms are common in offshore areas and there is excessive filamentous algal growth in many coastal areas.
- Fishing: overfishing, bottom trawling, and fish farming put pressure on the ecological systems in the Baltic Sea. Overall fishing effort fell by approximately 50 per cent from 2004 to 2021. Several fish stocks have been exploited above defined threshold values for sustainable stock management. Disturbances in fish stock lead to structural shifts in the marine food web, further affecting seabirds and marine mammals that prey on the fish stocks.

- Pollution (non-eutrophication): this consists mainly of pesticides, waste disposal, sewage, combustion, and oil. The Helsinki Convention has identified 132 polluting "hot spots" in the catchment area.
- Introduction of alien species. The rate of observed introduction of non-indigenous species has more than doubled in the 21st century.
- Construction (damming, dredging, and dumping of dredged material).

See figure 6 in Appendix. The Baltic Sea ecoregion, showing exclusive economic zones and larger Natura 2000 sites (ICES, 2020a).

Photos: unsplash.com

Chapter 4

Potential biodiversity impacts of OWFs

Although necessary, energy production is often in conflict with environmental values that are already under pressure. As described above, biodiversity in Nordic marine ecosystems is under pressure from climate change, overexploitation, and habitat destruction resulting from flooding, soil erosion, nutrient run-off from agriculture, and marine littering. This affects the functionality of the food webs and reduces resilience and resistance against further environmental changes.

This is why there is a high focus on understanding the environmental impact of new industrial developments in the marine environment, including OWFs. But there is also an increasing focus on understanding how new development projects can contribute to improving the natural environment, and there are examples of OWF operators aiming to be net biodiversity positive by 2030. In order to achieve this, more knowledge is needed on impacts, benefits, and approaches to estimate these.

OWF projects can affect biodiversity by introducing physical changes to the natural habitat, by producing noise and by creating electromagnetic fields from subsea or floating power cables. The impacts on species population levels can be beneficial, negative, balanced or absent. Different degrees and combinations of impacts are the most likely scenario. Cumulative impacts resulting from the combined environmental pressures of activities can be significant and should also be taken into account. The following chapter covers the main known biodiversity impacts from OWF development projects and indicates research needs to improve our understanding of potential impacts. For more detailed reviews on biodiversity impacts, please see the following publications: Degraer 2020, IMR 2020, WWF 2014.

Onshore aspects (arrangement from landfall and onshore transmission) are not part of the scope for this report.

4.1 Physical changes

The most important biodiversity impacts resulting from physical changes to the natural environment caused by the introduction of OWFs are habitat impacts, barrier or displacement effects and hydrodynamic changes.

4.1.1 Habitat effects

Habitat effects include both loss, degradation and transformation of habitats, but also habitat creation, including reef and refugee effects. Activities related to the construction of OWF projects, including pile driving and cable trenching, causing physical damage and smothering, result in a total local destruction of the benthic habitat. However, the impact is expected to be low at the population level, as benthic communities are widespread. It has also been suggested that vibrations from turbines can impact benthic habitats by changing the structure of the sediments (reviewed in IMR 2020).

OWF development projects represent the introduction of a hard substrate (turbine foundations, scour protection and turbine towers), which provide habitats for benthic species to colonise. This first colonisation of benthic species will be followed by attraction of crab, lobster, small fish and, finally, larger predatory fish and marine mammals (IMR 2020). The impacts will be different between fixed and floating installations, and installations at soft bottom locations will have a larger impact than on hard bottom substrates. The distance to other reef-like habitats should not be too large for new colonisations to happen. Concerns have been raised that the installations could act as steppingstones for the introduction of invasive species.

Another habitat effect is that that turbine bases can serve as refuge for fish and marine mammals due to the exclusion of fisheries and other marine traffic inside wind farm areas (depending on local jurisdiction). Exclusion of such activities can lead to protection for both fish and benthic communities inside a wind farm area, similar to a marine protected area (Hammar et al 2016). As the local ecosystem might benefit from the exclusion of fisheries and other marine traffic, it is important to note that this can lead to increased pressure on sensitive biodiversity elsewhere.

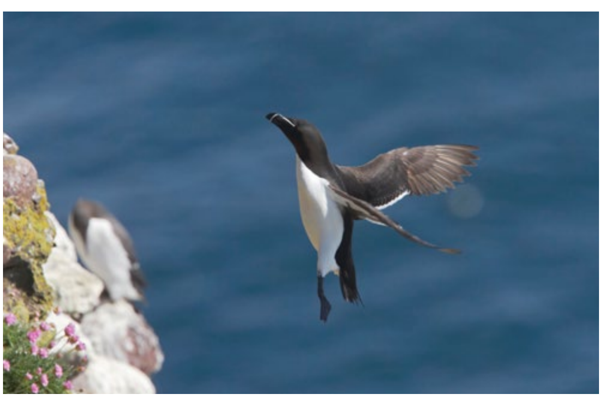
Experience from environmental monitoring in Belgium has not identified any large changes to fish populations linked to OWFs after nine years of monitoring (Degraer, 2020). Data from their investigations shows that fish populations were mainly influenced by temporal variations due to changes in climatic conditions rather than the small-scale effect of OWFs. The first signs of reef effects were seen by an increase in some fish species associated with soft sediment. We suggest that this is a probable effect from the exclusion of fisheries combined with increased food availability.

More research is necessary to better understand the effects of OWF projects on habitats and a methodology must be developed to determine the effects of OWFs on biodiversity.

4.1.2 Barrier effects

Barrier effects happen when wind farms hinder species in their regular movements to and from breeding grounds or other regular use of an area. The extensive anchoring arrangement for floating OWFs could potentially lead to underwater barriers for marine mammals. Such effects are hard to quantify and may vary over time and space, and also depend on the extent of wind farms in an area.

Another physical impact is the risk of collision with rotor blades for seabirds, migrating birds (shorebirds, waterfowl and land birds) and bats flying at turbine rotor height. The resulting mortality may have an impact at the population level for long-lived species with delayed maturity, small clutch sizes, and a declining population trend.



Razorbills (Alca torda) are among the seabirds most vulnerable to displacement by OWFs in the Nordics.
Photos: scanpix.dk

For birds, there are significant species-specific differences in behaviour that affect the risk of injury. Some species will avoid installations (being displaced), some are indifferent, and some are attracted to the OWF installations. Examples of species avoiding wind farms are Northern gannet (*Morus bassanus*), Common guillemot (*Uria aalge*), Razorbill (*Alca torda*). Examples of species attracted by windfarms include Lesser black-backed gull (*Larus fuscus*), Herring gull (*Larus argentatus*), Little gull (*Hydrocoleoeus minutus*), Great black-backed gull (*Larus marinus*) and Sandwich tern (*Sterna sandvicensis*). Gulls are attracted to the installation because of feeding resources and use the installations as resting stops and as lookouts for finding fishing vessels, and the installations have increased the gulls' territory by providing resting spots (Degraer at al 2020).

Northern gannets (Morus bassanus) often forage inside OWF areas.
Photo: Andreas Trepte. CC BY 2.0 via Wikimedia Commons

Sandwich terns (Thalasseus sandvicensis) generally avoid OWFs.
Photo: Charles J. Sharp. CC BY 2.0 via Wikimedia Commons

There is uncertainty regarding the extent of the actual impact of bird collisions, as monitoring and carcass registration are not an option offshore. Collison risk models are used to assess this impact (Degraer et al 2020). The models use wind farm configuration and species-specific parameters (dimensions, flight activity, and local density) as input. Recent studies have indicated that avoidance rates for seabirds are higher than previously anticipated, at around 99 per cent (Skov 2018, Brabant 2020, Degraer 2020).

Bats (order: Chiroptera) are facing numerous threats worldwide. As they have a low reproduction rate, it is important to consider them in wind energy development. Bats are at risk of collision and barotrauma, an injury caused by sudden pressure changes around the moving blade. Bats have been shown to use wind farms and offshore installations as sites for resting and mating (Gaultier 2020). There is a lack of knowledge of the potential impacts of OWFs on bat populations.

It is known that marine mammals can avoid OWFs if installations are perceived as obstacles. However, they can also be attracted to the area because of higher food availability (fish refuge effect as explained above). It has been suggested that OWF installations may contribute to ghost fishing by entangled fishing gear, but there is limited understanding of the actual impact.

To better understand the environmental impacts of barrier effects from OWFs, there is a need to better understand aspects like collision risk and avoidance behaviour for birds, displacement effects for marine mammals and ecosystem effects of artificial reefs in different environments.

4.1.3 Hydrodynamic changes

OWF installations have the potential to alter local hydrodynamic conditions. Hydrodynamic changes can happen as the OWF installation will reduce the wind speed in the wake of the installation, which again can affect turbulence, wave energy, current conditions and vertical movement of water masses that in turn could alter the water quality stratification etc. As summarised by IMR (2020), studies on hydrodynamic effects of OWFs on the demersal habitat are not conclusive.

4.2 Noise

In different project phases, OWF development will cause underwater noise that can be perceived by most fish and mammals.

During site characterisation, noise is generated by seismic surveys. Noise from the construction phase is mainly caused by pile driving and potentially from drilling. In the operation phase, noise is produced by generators and transmission systems inside the turbines; this noise is significantly less than in the construction phase.

Pile driving is used in the construction of fixed OWFs and represents the most important acute sound risk from OWF development. Pile driving refers to the process where large hydraulic hammers with 1–2 blows per second are used to drive steel pipes with diameters ranging from 1.4 to 8 metres depending on the type of installation. Excessive sound is produced when such large quantity of energy is introduced under water. Each pile requires up to 500 blows, and the operation lasts for several hours. The duration of the sound pulses increases with increasing distances, and at distances between 1,600 and 16,000 metres from the pile driving, the sound can be perceived as continuous.

Sound from the operation phase is variable and will to a large degree be affected by wind speed and the type of construction. There is not much information available from operational sound from floating installations. Short blows have been observed from the anchoring chains in the Hywind demo project. Potential effects will most likely be local.

The main threats to fish from OWFs are disturbance of spawning grounds and sound effects during construction phase. The potential sound effects are especially relevant for clupeids (herring) and gadoids (cod).

Temporary and permanent hearing loss in harbour porpoises at close range has been reported (Brandt 2018). Disturbance and displacement of up to 20

Various fish species like Pike (Esox lucius) and Perch (Perca fluviatilis) may be affected by electromagnetic fields induced by submarine cables from OWFs, but more research is needed. Photo: Gilles San Martin. CC BY 2.0 via Wikimedia Commons

Cod (Gadus morhua) in the North Sea are attracted to artificial reefs that OWFs provide, which may impact fisheries. Photo: scanpix.dk

km for 2–3 days have been shown for this species after pile driving. As the construction phase is temporary, the seriousness of the impacts on an area will depend on the extent of the construction work.

Fish and marine mammals have different hearing thresholds and will consequently react to, and be affected differently by, various sources of noise. Studies performed on the effects on marine species over the last decades are somewhat inconclusive, and hence a precautionary approach should be adopted (Xodus for Hywind Scotland, Statoil ASA, 2015).

4.3 Electromagnetic fields

Subsea cables produce static and variable electromagnetic fields. Cables could be buried or floating, depending on the type of installation. The effects will depend on the type of cable, burial depth, type of current etc., and it has been suggested that this could impact fish and benthic organisms. However, effects are not well documented.

For benthic communities, it is expected that electromagnetic fields will potentially affect a small fraction of the community in the vicinity to the cable. Electromagnetic fields could also influence the migration of salmonids and eels, as well as affecting species with electroreceptors, such as sharks, rays, sturgeons and lampreys. More knowledge is needed to understand the impact of electromagnetic fields on biodiversity.

4.4 Cumulative impacts

To understand the overall biodiversity impacts of OWFs in an area, cumulative impacts must be taken into account. The large up-scaling of OWF development in the Nordics and elsewhere will translate into extensive deployment of activities related to construction, operation, and decommissioning. Different phases of OWF development, happening simultaneously in an area, each have different pressures and impacts on the environment over different periods of time.

Individual OWF development projects are subject to systemised assessments of pressures exerted on marine ecosystems, but evaluations on a larger spatial scale and long-term assessments of simultaneous OWF development projects are necessary to provide a holistic knowledge base for strategic planning. Ideally, evaluations and assessments should take a dynamic approach, using survey data to represent species population distribution at the basin level and predictive models based on basin-relevant data repositories, including the temporal aspects of OWF development projects. A key challenge is to understand how effects accumulate, what the important ecological thresholds are and when they are exceeded. It would also be easier to estimate cumulative impacts if the environmental impact assessments performed in the various countries were performed with comparable endpoints.

Photo left: unsplash.com
Photo right: Vattenfall Nederland. Offshore Windpark Egmond aan Zee 5 years. License

Chapter 5

Frameworks for mitigating biodiversity impacts and stakeholder engagement associated with OWF development

To minimise conflicts with environmental and societal values associated with the development of renewable energy, several international frameworks and guidelines have been developed. These are all relevant for the Nordic countries and are summarised below.

5.1 International frameworks

The European Green Deal and the EU's biodiversity strategy provide a framework for policy on climate change and biodiversity in the EU. The Birds and Habitats Directives are key components and serve to ensure that species and habitat types are maintained or restored to a favourable conservation status throughout their natural range in the EU. The focus is Natura 2000 sites, a network of core breeding and resting sites for rare and threatened species, also including some rare natural habitat types that are protected in their own right.

Natura 2000 sites stretch across all 27 EU countries, on land and at sea (European Commission, 2020a). Natura 2000 sites are not intended to be "no development zones", but the directives require new plans or projects to be undertaken in a way that does not adversely affect the integrity of the Natura 2000 site. The directives entail that the competent national authority must ensure that assessments of significant effects arising from OWF plans are carried out.

To ensure sustainable development of offshore energy production, the EU has also adopted the Marine Spatial Planning Directive (EU, 2014) to create a common framework to reduce conflict between sectors and create synergies, and to encourage investments, cross-border cooperation, and environmental conservation.

Public participation is part of the Commission's EIA and SFA procedures. Early stakeholder consultation and engagement to improve the environmental information supplied to decision makers are key components.

Last year, the EC published the "Guidance document on wind energy developments and EU nature legislation" (EC, 2020a). The document provides guidance on how to ensure that wind energy developments are compatible with the Birds and Habitats Directives. The document refers to examples of good practice in 39 case studies. The case studies are not intended to be prescriptive but provide a framework/inspiration for developing solutions on a case-by-case basis.

IUCN and the Biodiversity Consultancy published earlier this year the guidance document "Mitigating biodiversity impacts associated with solar and wind energy development" (Bennun, 2021). The document has a global scope and aims to provide practical support for risk management and to minimise unwanted biodiversity effects. The document explains the mitigation hierarchy in detail, examine potential impacts and mitigation approaches for different renewable energy technologies. The report also provides 33 case studies to illustrate main points and relevant mitigation measures. Around 20 case studies presented in the two guidance documents are from the Nordics and neighbouring countries.

5.1.1 Mitigation hierarchy

The mitigation hierarchy as described in the guidance documents (and references therein) provide a similar framework to minimise conflicts with environmental and societal values. The framework applies to all phases of a project and is based on the following hierarchy of actions: avoid, minimise, restore, and offset potential unwanted effects. Successful application of the hierarchy is based on continuous evaluation of a measure's efficacy followed by adaptive management of measures.

Avoidance is the most important measure and is based on actions taken to avoid impacts in the first place. Examples of effective avoidance measures include ensuring that projects are not situated in an area with sensitive environmental resources, designing the project in a way that avoid conflicts with other interests, and planning activities in a way that has the least environmental impact.

Minimisation applies to effects that cannot be avoided and can contain measures affecting the physical design of the OWF, measures implemented during operation like noise reduction, and curtailment (explained further down).

Restoration is a process of reversing the degradation of ecosystems. Restoration aspects can be incorporated into the OWF project's design to repair previous impacts from other industrial activities in an area.

Offsets are measures taken to compensate for effects that cannot be handled by the steps above.

5.2 Stakeholder engagement

Good stakeholder engagement processes are important to identify and manage biodiversity risks and to understand other potential conflicts with sea users. Stakeholder engagement can take place during strategic planning performed by the government and/or during the planning of specific projects performed by operators. Good environmental practice for stakeholder engagement has been described in governance standards like the OECD Guidelines for Multinational Enterprises, IFC Performance Standards and the UN Global Compact.

In the EU, stakeholder engagement (public participation) is legally embedded in the Habitats Directive and in the EIA and the SEA Directive. The guidance documents state that consultation with experts, relevant authorities, NGOs, potentially affected groups, and the general public can improve the environmental information available to those carrying out assessments and to decision makers. A good process could minimise potential conflict and delays.

Their guidance on effective stakeholder consultation includes early involvement, identifying relevant groups and choosing the right form of communication. Communication forms include:

- Informing: one-way flow of information from the proponent to the public.
- Consulting: two-way flow of information from the proponent to the public.
- Participating: two-way flow in which the public is involved in analyses and voluntary decisions on project design.

Participatory planning is the most recommended approach. The process needs to be transparent and open; the language should be easy to understand, and the data should be made open to the public when requested (European Commission 2020a). The EC highlights that inter-sectorial consultations (i.e. between wind and grid development projects) may lead to innovative approaches and flexibility to meet other stakeholders concerns.


Photos: *unsplash.com*

Chapter 6

Examples of accommodating biodiversity and stakeholder engagement in Nordic OWF development

In the following chapter, we identify key elements to accommodate biodiversity and stakeholder engagement in further OWF development in the Nordics. The key elements are illustrated by five case studies described in detail in chapter 7.

6.1 Strategic planning

Strategic planning is the first step in any OWF development and is important for identifying, avoiding, and minimising potential conflict with environmental or societal values. It is the most effective measure for mitigating biodiversity impacts and is based on planning activities in time and space. Strategic planning of OWFs happens in several phases, from the government's process of opening areas to the operator's process of understanding project-specific risks. Effective avoidance through site selection can reduce project risk and requirements for further mitigation.

The abundance of wind energy allows for some flexibility and especially floating wind provides opportunities for careful project siting to minimise pressures on the environment. All stages of strategic planning can be informed by Marine Spatial Planning, a process that brings together multiple users of the ocean, including energy, industry, government, conservation, and recreation.

The Danish strategy can serve as good example of a government-led process of opening areas for OWF development based on Marine Spatial Planning and is described in Case 1. The case documents how the Danish government works with siting for OWF development and stakeholder engagement processes. The overall process starts with general site-studies, identifying "no-go" areas, before continuing with fine-screening processes to identify locations with the best conditions for energy production with the least environmental impact. The case is relevant for the other Nordic governments and can inspire efficient, predictable, and low-risk processes for different stakeholders when opening new areas for OWF development. The Danish system removes risk from the operators and might be more suitable when assessing smaller sea areas.

Hywind Scotland Pilot Park project serves as a good example of project-specific avoidance through microsite characterisation. The process is presented in Case 2. In Scotland, operators take more responsibility for the siting process than in Denmark. The case describes how the operator evaluates different locations within an assigned area. The final location is selected on the basis of impacts on biodiversity, among other aspects. The project illustrates the importance of detailed on-site mapping of the ecosystem to decide on a final location that minimises the environmental impact.

Key components of strategic planning, as described in more detail below, include stakeholder engagement, availability of environmental data, identification of potential cumulative impacts, understanding opportunities for habitat enhancement and requirements for offsetting measures.

6.1.1 Stakeholder engagement

Effective stakeholder engagement is critical for the successful development of OWF projects. Stakeholder engagement should be a continuous process and is especially important in the planning phase. There are significant differences in how the Nordic countries currently practise stakeholder engagement in wind energy development. This highlights the potential for experience transfer across borders and industries in these countries.

Current practice and experience from the Nordics
In Sweden, the operators themselves oversee all stakeholder interaction processes. In Norway, the government includes stakeholders in strategic planning and work with marine management plans, both when assessing areas on a high level and when opening areas for OWF development applications. Operators handle stakeholder engagement processes for their specific projects on a more detailed level in cooperation with the authorities that lead the licence application process. The Norwegian authorities engage stakeholders for input to operators' plans for assessment work in the planning phase and for input to the proposed mitigating measures for the construction and operational phases. This framework is based on

experience from the petroleum industry. Denmark has a similar process to Norway, however the government is responsible for the majority of the process, as detailed in Case 1.

In Norway, onshore wind development has generated considerable conflict between the Norwegian Water Resources and Energy Directorate (NVE) and nature protection interests. Key issues in the conflict are linked to the absence of transparency in the licensing process and poorly managed stakeholder engagement processes (Gulbrandsen L.H., 2021). Based on this experience, efforts are now being made to ensure improved stakeholder processes for OWF development projects and, as stated in the government white paper from 2021, "successful development of OWFs in Norway depends on the successful coexistence with other industries and that environmental and societal aspects are accommodated in a good way" (The Norwegian Government, 2021).

The Norwegian government is working actively towards this goal and has initiated a collaboration forum for OWF development (September 2021). The forum includes representatives from key stakeholder groups and should ensure predictable premises for stakeholders and promote coexistence. The Norwegian Oil and Gas Association is also taking an active role in the process. The Danish government's strategy (Case 1) for stakeholder engagement in OWF development is considered successful and can serve as a good example for establishing a predictable framework for the operators and involved parties.

Good examples of OWF stakeholder engagement processes in Scotland, France, and Germany

In Scotland, the government facilitates the framework for stakeholder engagement or OWF development at the strategic level and is also in charge of the Scottish Energy Research Programme (ScotMer). ScotMer involves collaboration between industry, environmental NGOs, Statutory Nature Conservation Bodies and other interested stakeholders to identify knowledge gaps when assessing the environmental and socioeconomic impacts of OWF development and defining the framework for a research programme. This has proven successful in establishing a common understanding of the opportunities and challenges related to OWF development in Scotland.

At a strategic level, the Scottish government maintains a high focus on stakeholder engagement when it comes to renewable energy development, commercial fishing, shipping, defence interests, and aviation. It also provides guidance on how effective coexistence between offshore wind and commercial fisheries should be facilitated. Developers are expected to engage in discussions, particularly regarding assessments of cumulative effects, socioeconomic impacts and commercial fisheries, and to undertake necessary project-level community and stakeholder engagement. Discussions with stakeholders and regulatory bodies help to identify the

relevant best practice guidance (for all phases of development) and the methodologies and data to be utilised in impact assessments. Developers are expected to take more responsibility in stakeholder engagement processes in the project phase than in Denmark.
The EC guidance document (2020a) refers to good examples of stakeholder cooperation related to OWF development at the national level in Germany and France. In both countries, similar sets of procedures are applied, including:

- Collaboration on setting high-quality criteria (thresholds) to assess the biodiversity effects of OWF development.
- Organising and coordinating research and monitoring.
- Developing and providing advice on methodologies for the private and public sector that can be used to assess and reduce environmental impacts.
- Organising conferences and workshops and participating in international events.

Lessons learned from the O&G industry
There is considerable knowledge and experience related to stakeholder engagement that can be transferred from the O&G industry to the OWF industry. The industries operate in the same environment and have similar stakeholder groups. One important difference is that OWFs and O&G have a different use of, and impact on, the area, which must be reflected in stakeholder engagement processes. O&G has discharges to the marine environment (produced water etc.) but occupies a limited area compared to what planned OWF developments will represent. OWF development areas exclude fishing and other maritime activities to a larger extent than existing O&G installations. Due to anchoring cables etc. from floating installations, such projects will probably entail even larger exclusion zones than fixed foundations.

Experience from Norway and Scotland shows that OWF projects are less successful in undertaking good stakeholder engagement processes than the O&G industry. One reason can be that OWF projects are complex consortia with different partners in different phases of the project compared to most O&G projects. This implies that it is more difficult to ensure positive interactions to establish trust and mutual understanding between operators and various stakeholders.

Another complicating factor is that some OWF developers do not have previous experience from working in an offshore environment. A lack of understanding of local regulatory regimes and local interests can also make it difficult for operators to ensure good processes. A transparent and structured process led by governments during strategic spatial planning could minimise risk for all involved parties.

6.1.2 Data

Relevant and updated information on the natural ecosystem and activities of other users of the ocean is required for relevant strategic planning of OWFs. Environmental data collected during strategic impact assessments, or during project-specific investigations before a project is started, is referred to as a baseline study. Data collected to document the effects of an activity after it has started is often referred to environmental monitoring data. Due to large variations in the marine ecosystem over time, baseline studies should be conducted for a minimum of three years (IMR 2020). Global warming is also affecting ecosystems and leading to more rapid changes, which calls for continuous investigations.

For strategic planning to be efficient and transparent, collected data should be made available for interested parties. There are several good examples of successful data gathering and sharing from the OWF and O&G industries.

The Danish government's process for strategic planning is partly based on a transparent and efficient framework for data sharing (Case 1).

Belgium, Scotland and Norway are other examples of countries where governments are taking responsibility for sharing data. In Belgium, all data from baseline studies and environmental monitoring is available to the public from the government's webpages: https://odnature.naturalsciences.be/mumm/en/windfarms/. In Scotland, advisory groups are being set up to ensure that relevant data is collected for OWF projects, and data is made available on the Marine Scotland Information web portal (https://marine.gov.scot/). This has shown to build trust and transparency of accumulated knowledge and facilitate stakeholder dialogue.

Another good example of sharing environmental data is the Environmental Monitoring Database (MOD) from the O&G industry in Norway. The database comprises species occurrence records as well as chemical and geology records of data collected from environmental monitoring of petroleum-related activities in Norway since 1996. The Norwegian Petroleum Directorate's approach of publishing all planned and ongoing seismic surveys is another good example of efficient sharing of information related to use of ocean space.

6.1.3 Cumulative effects

Individual OWF development projects are subject to systemised assessments of pressures exerted on the marine ecosystems, but evaluations on a larger spatial scale and long-term assessment of simultaneous OWF development projects are necessary to provide a holistic knowledge base for strategic planning. This can be performed as part of marine spatial planning processes at national levels. Assessments of cumulative effects are a requirement under the Habitats Directive as well as the SEA and EIA Directives. There is not enough knowledge to understand these impacts and research is ongoing; examples of recently established research programmes in Scotland and Norway are described in Case 3.

6.1.4 Opportunities for habitat enhancement

If properly planned, OWFs can enhance seabed habitats and restore previously degraded ecosystems. In the Netherlands, there are several initiatives working to find technological solutions to accommodate species restorations (e.g. the Rich North Sea and the Flat Oyster Consortium, Bennum 2021). Their main focus is oysters, but they are also looking into other species. A key component in planning such activities is to assess how compatible the species of interest is with location-specific environmental factors. In the Netherlands, it is a requirement in the licensing process that OWF installations provide nature-enhancing solutions (The Ministry of Agriculture, Nature and Food Quality, The Netherlands, 2020).

Using OWFs as a means of active biodiversity restoration, apart from the exclusion of fisheries and the artificial reef effect, does not seem to be a major focus in other parts of the North Sea or the Baltic Sea. More knowledge is needed on effects and benefits before such options are explored in these areas.

6.1.5 Offsetting

Offsetting measures are applied when biodiversity impacts cannot be avoided by other mitigation measures. It represents the last step in the mitigation hierarchy. According to IUCN, offsets should be designed to meet specific and measurable goals that directly relate to a project's residual impacts, and should aim to achieve no net loss or a net gain in terms of biodiversity. One example of a project where offsetting measures have been implemented is the Hornsea 3 project in the UK part of the North Sea. The project was shown to impose an unacceptable risk to the population of Black Legged Kittwakes and was required to compensate these impacts by building artificial nesting sites. Offsetting as a measure to compensate biodiversity impacts is currently not high on the agenda in the Nordic countries. While not directly linked to biodiversity, Denmark compensates fishermen for lost income due to OWF developments, and an agreement to compensate fisheries must be in place for OWF operators to obtain a licence.

6.2 Construction

When strategic planning is conducted and a site is selected for OWF development, decisions on how the project will be matured prior to construction are made during project planning. During this phase, several mitigating measures could be implemented in a project. First and foremost, projects could implement and define technological criteria for the project. This includes criteria for accommodating biodiversity as well as commercial and technological specifications. Examples could be:

- Modification of the physical design of the project infrastructure during construction to reduce operation-related impacts on biodiversity.

- Configuration of turbines to limit impacts on biodiversity:
  - Altering the minimum distance between turbines.
  - Aligning turbines parallel to, and not across, main bird migration routes or general flight directions.
  - Arranging turbines in clusters with corridors between them that provide passage through the site.

The impacts on biodiversity during the construction phase of OWF development greatly depend on the surrounding nature and the extent of the development project, as well as which technologies are being developed (bottom-fixed, monopile, floating etc.). As mentioned, the most effective measures should already have been taken during the planning phase, and from this point on, mitigation measures are highly location dependant.

The construction phase involves a wide array of activities to be conducted and represents several potential impacts on biodiversity. In some cases, opportunities for new, or more efficient, mitigation measures are identified after construction has begun. Also, sometimes during the construction phase unforeseen issues can arise that necessitate changes in the mitigation plan, or the introduction of new measures. This can result in further impacts on biodiversity. Therefore, it is of outmost importance for the project to have a flexible and active environmental impact assessment process that can accommodate possible changes to the project plan.

Good practice mitigation measures for the construction phase are generally applicable to all types of development projects, including OWF development. Some appropriate practices to avoid and minimise impacts during construction are proposed below.

Seasonal restrictions/avoidance through scheduling involve changing the timing of construction activities to avoid disturbing species during sensitive periods of their lifecycle. This is the most effective means of construction phase mitigation and is also an important consideration in avoiding and minimising aggregated and cumulative impacts. The concept is widely established in construction practice and environmental permitting in several different industries and regulatory **regimes.**

Minimisation in the construction phase includes abatement controls and operational controls. This includes reducing and minimising activities with an impact on biodiversity. An example of this is the employment of bubble curtains (Case 4) as a measure to reduce the impact of noise from pile driving and blasting activities on organisms.

Restoration and rehabilitation work could be relevant in OWF development projects where construction makes environmental damage inevitable. Temporary project footprint areas onshore, including export cable laydown and landfall, should always be restored upon finalising construction. Offshore, the seabed disturbance should be reduced to a minimum. For development areas located in degraded coastal or sea areas, such as heavily trawled areas, it is encouraging to look into possibilities for habitat restoring/enhancing measures to create benefits to biodiversity. There are currently several ongoing R&D projects regarding habitat restoration, as commented above.

6.3 Operation

Most offshore wind farms constructed today have an expected lifespan of approximately 25 years. This means that most OWFs will have an operational phase of at least 25 years, determined by whether the OWF will be repowered or not.

Minimisation of the impact from activities related to operations is very important in order to reduce potential impacts on biodiversity. Compared to onshore wind farms, OWFs have generally higher demands for maintenance and servicing. This means significant service and maintenance vessel activity during the operation phase, which can lead to disturbance of populations and organisms by noise and light pollution, as well as discharges to the sea. It is therefore important for these activities to be well organised and planned in order to minimise impacts from these operations.

Collision risk and the potential for birds and bats colliding with turbine blades is one of the main risks for biodiversity during the operation phase. When it comes to collision with turbine blades, the most effective measure is to shut down turbines temporarily when priority species are at risk. Such periods could be pre-defined based on the activity of different species during certain life-events of those species. Alternatively, where species presence is less predictable, real-time shutdown on demand, based on radar or other sensor systems, is likely to be more practical. This may also represent significant surveillance costs.

Other measures to reduce collision risk mainly focus on modifications to wind turbines themselves, and to overhead transmission lines associated with the onshore electrical infrastructure. Such measures could include increasing the visibility of turbine blades by the use of paint.

Environmental monitoring should always be an integrated part of planning phases, construction phases and operational phases during OWF development. Effective mitigation of project impacts requires a comprehensive understanding of biodiversity features in an area and how these change over time with regard to OWF development activities.

Information derived from monitoring surveys can be used to evaluate the effectiveness of mitigation actions and inform adaptive management to ensure the project is set to meet its biodiversity objectives. Monitoring indicators should include measurements of both the state of project biodiversity, in addition to project and area impacts, as well as mitigation responses including potential offset success. Specific monitoring needs are highly dependent on regulatory requirements, company standards, as well as lender safeguards.

Some general conclusions regarding environmental monitoring philosophy can, however, be established regardless of the mentioned aspects. First and foremost, it is important to ensure that the level of effort in the monitoring is commensurate to the risk to biodiversity. Also, monitoring surveys could be coordinated between developers in order to ensure a holistic perspective in the monitoring. Data obtained through monitoring could be shared to ensure transparency, help developers maintain commitment to good mitigation practice, and contribute to wider conservation efforts. Good examples of such monitoring practice are shown in Belgian monitoring programmes for OWFs and in Norwegian oil & gas environmental monitoring (Case 5).

Photos: unsplash.com

Chapter 7

Case studies

The cases have been selected to reflect important mitigation measures relevant for the different phases of OWF projects in a Nordic context. The cases reflect solutions for emerging challenges and knowledge gaps. As described above, Cases 1–3 represent examples of practice relevant for the planning phase, Case 4 is relevant for the construction phase and Case 5 is relevant for the operation phase.

CASE 1

Strategic planning – example from Denmark

What: Strategic planning with thorough screening processes has been a key factor to the success of Danish OWF development and will be for future development.

Relevance: Such screening processes, together with impact assessment processes, are seen as vital measures for identifying natural resources of high importance to biodiversity. In that way, further strategic planning can take place with avoidance as the main mitigating action for accommodating biodiversity and ecological values.

Process: As a result of Denmark's energy policy deal of 2004, the Danish government agreed to develop two OWFs, each producing 200 MW. In connection with the decision on which areas to develop, a screening of different areas was conducted, evaluating aspects ranging from physical factors, such as wind condition and annual wave height, to ecological factors, such as spawning grounds for fish and nesting areas for birds. In addition, several stakeholders were engaged in the screening process and a total of 59 consultative responses were submitted in the process. Stakeholders ranged from OWF operators to NGOs and private individuals.

In 2007, the Danish Energy Agency published *Future OWF locations – 2025 (Fremtidens Havmølleplaceringer – 2025)*, a committee report on mapping future OWF farm locations. The report points to a number of possible locations that could possibly accommodate an expansion with additional OWF turbines with a total capacity of approx. 4,600 MW. A thorough consultation process was carried out involving all authorities with responsibilities at sea, relevant organisations and the general public. The report also included strategic environmental assessments, as well as studies on the visual consequences of a possible expansion. As a result, the Danish Energy Agency announced their *OWF Action Plan 2008 (Havmøllehandlingsplan 2008)*. In the following years, several areas were "reserved" by the Danish government for OWF development.

In 2012, the Danish authorities published their screening of near-coast locations for OWFs (within 20 km from coastline). The screening first and foremost focused on the technical and economic feasibility of areas. But it also covered relationships to existing action plans, management plans, and protections plans, as well as more specific topics like environment and nature conservation, cultural heritage, the visual landscape, other natural resources (oil and gas, aquaculture, minerals, fisheries etc.), and shipping.

Following the Danish Energy Agreement of 29 June 2018, the Danish Energy Agency performed a coarse screening of the entirety of Danish waters for possible locations for OWF development. The screening revealed that Denmark has offshore areas with a potential for developing a minimum of 12.4 GW.

As a result of the screening performed by the Danish Energy Agency in 2018, a further fine-screening of selected areas was performed in 2020 (DEA, 2020a). The fine-screening process was designed to confirm that the areas were practically fit for further development, in addition to ranking the different areas with regard to environmental aspects, suitability of seabed features, technological layouts, and energy potential, as well as economic feasibility.

A GIS-based sensitivity analysis formed the basis for an assessment of impacts on the environmental aspects of OWF development in the different areas. The analysis was based on available information on environmental resources for the relevant areas, as well as standalone environmental studies (DEA, 2020b); (DEA, 2020c). As a result, areas and sub-areas within proposed OWF locations were ranked based on sensitivity to the development of wind turbines and cables. The analysis aimed to highlight areas where the environmental impact would remain as low as possible. Along with the analysis, the fine-screening presents descriptions of the environmental aspects and possible impacts of each potential location for OWF development, as well as for associated export cables and landfall. This was to help with further decision-making and the totality of the fine-screening process.

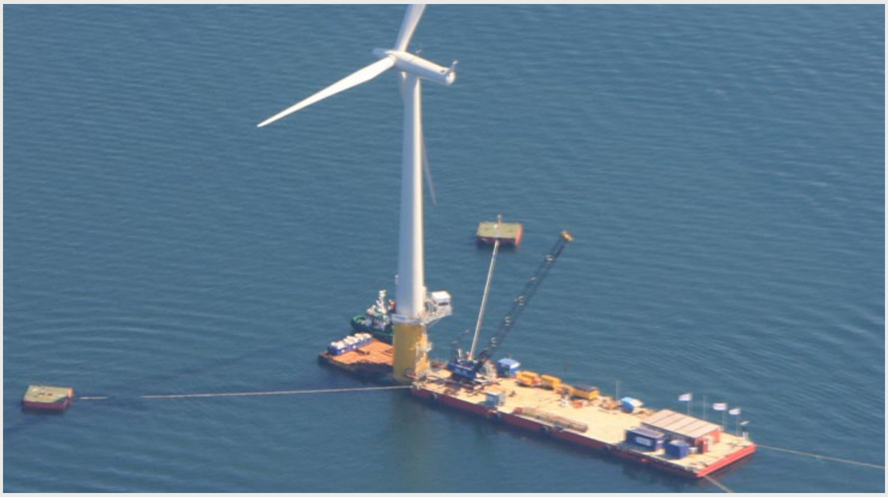
Benefits

In order to assess the aspects of the fine-screening process related to technological layouts, energy potential and economic feasibility, predefined areas had to be selected. Therefore, prior to assessing these issues, environmental considerations and analyses had to be carried out. As a result, areas with environmental showstoppers and no-go zones were ruled out of further studies.

See figure 7 in Appendix. Overview of environmental sensitivity for the three areas assessed in the fine-screening process, and overview of sensitivity for human impact for the three areas assessed in the fine-screening process (DEA, 2020a)

CASE 2

Avoidance by site characterisation – Hywind Scotland Pilot Park Project



Hywind Scotland is the world's first commercial wind farm using floating wind turbines, situated 29 kilometres off Peterhead, Scotland.
Photo: Jarle Vine. CC BY 3.0 via Wikimedia Commons.

What: The evaluation of potential sites for the Hywind Scotland Pilot Park.

Relevance: The case provides an interesting example on how detailed mapping of an area allowed for optimal siting of a floating OWF project in terms of environmental and technical aspects.

Process: Identification of a suitable location for development of the project and route for cable to shore began in 2009 and was influenced by a number of factors, including:

- Water depth – the turbine units require, in general, water depths of more than 90 metres.
- Proximity to the grid – due to the relatively small scale of the Pilot Park (30 MW), potential development sites needed to be close to the coast to facilitate cost-effective export of power to the electric distribution grid without offshore substation and transformation.
- Access to sheltered deep-water areas inshore for turbine unit assembly.
- Proximity to a deep water navigation route – once assembled, the turbine units were towed in an upright position to the Pilot Park site. Therefore, the navigation route between the inshore assembly area and the Pilot Park site had to be of sufficient water depth to accommodate the unit's towing draft.
- Suitable seabed conditions – an even seabed, with sufficient soil above bedrock was preferred, although not required, for ease of installation.

Based on this, two locations in Scottish waters which met all or most of the above criteria, were selected. As a result of feedback from conservation bodies and other stakeholders, such as fisheries, Buchan Deep was selected due to it being further offshore with less environmental sensitivity. The Buchan Deep site also offered better availability of grid connections.

The project then carried out more detailed constraints mapping and stakeholder engagement for an area to be searched within the Buchan Deep to identify a preferred area for development.

Initial site assessment focused on the evaluation of offshore constraints for the turbine deployment area. Once a suitable offshore location for the project was identified, further work was undertaken to identify the preferred export cable route, cable landfall and onshore grid connection.

The initial area was split into two parts by the Forties Pipelines, operated by BP. It was decided early on that the Pilot Park would be located either north or south of the pipelines.

A number of factors contributed to the decision to locate the Pilot Park to the north of the pipelines. Despite the area to the north of the pipelines having less energy output potential, the following factors were key in the decision to go to the north of the pipelines:

- Locating the Pilot Park to the north of the pipeline avoided any need to cross the BP pipeline, as the export cable could exit the area at the north-west corner.
- *Sabellaria spinulosa* reefs (common name Ross worm) were recorded in the area. However, in the area to the north of the pipeline, the extent and quality of the reefs is considerably less than the extent and quality of reefs located to the south of the pipeline.
- The soil conditions for suction anchors are considered to be better north of the pipelines. Also from a geohazard point of view, the area north of the pipeline was preferred.

Benefits

Overall, although benthic survey work identified the presence of *Sabellaria* biogenic reefs in parts of the wider area, the best areas for these were in the southernmost parts of the area, away from the proposed turbine deployment area. Any biogenic reef present in the northern half of the area where the wind turbines are sited is very sparsely distributed, covers very small areas, and is rated as being of low reef potential and, based on the proposed indicative turbine layout, will not be impacted. Similarly small, isolated patches are also present at intervals along the export cable route, mainly in the deeper, offshore half. Where possible, the cable has been routed to minimise impacts on areas of *Sabellaria*. The company's own assessment of impact significance is shown in Table 1.

Table 1. The assessment of impacts during construction and installation from the Hywind Scotland Environmental statement, evaluations of Sabellaria reef (Equinor, 2015).

Assessment of impact significance		
The anchoring of the turbines and placement of scour protection and inter-array cables in the turbine deployment area and the installation of the export cable to Peterhead will result in a direct long-term footprint of only a very limited area of seabed. Less than 0.3 km2 and a larger but still localised area of peripheral temporary disturbance during construction amounting to just over 1 km2. Although very small areas of potential low-graded Annex I biogenic reef could be affected together with patches of rocky and stony reef, the great majority of this area is occupied by biotopes of no specific conservation concern which are present on a wider scale throughout this area of the North Sea. It should also be noted that the seabed in this area (at water depths of over 50 m) is already impacted by seabed trawling fishing gear (evident from seabed surveys). The much larger areas of potential Sabellaria reef noted in survey work to the south of the Project area will be avoided; the decision was made early in the process to actively avoid these areas of potential reef. In addition no Priority Marine Features appear to have a significant presence here. On this basis, the subtidal habitats and species potentially affected by the Project are considered to be of medium sensitivity to disturbance/loss: the magnitude of effect as justified above is considered minor resulting in a level of impact of minor and not significant. This impact is certain to occur.		
Sensitivity/value	**Magnitude of effect**	**Level of impact**
Medium	Minor	Minor
Impact significance – **Not significant**		
Mitigation (subtidal)		
> No mitigation measures have been identified for this impact as it was concluded that the impact was not significant. allhough it should be noted that the proposed export cable has been routed to minimise impact on areas of *Sabellaria*.		

CASE 3

Assessing cumulative effects – examples of research activities in Norway and Scotland

What: The large up-scaling of OWF development will translate into extensive deployment of activities related to construction, operation, and decommissioning in the Nordics over a long period of time. Creating a national or regional database that facilitates an overview and of different activities is necessary to identify the potential for cumulative effects. A key challenge is to understand how effects accumulate, what the important ecological thresholds are, and when they are exceeded.

Relevance: Research is required to close knowledge gaps related to **cumulative impacts.**

Examples: One example from Norway is the MARCIS (2021–2025) project, funded by the Norwegian Research Council. A key research target is to set marine activities in a larger context by developing a spatially explicit decision-support tool. The project will specifically address the cumulative impacts of both oil & gas and offshore development (offshore wind, offshore aquaculture, CCS, hydrogen production, shipping, fisheries etc.) on seabirds. The behavioural effects of floating turbines on migratory birds will be studied at Hywind Tampen.

The Scottish government (Marine Scotland) has initiated a research project called "Cumulative Effects Framework for Key Ecological Receptors" (CEF), which will run from June 2020 to Spring 2022 (UK Centre for Ecology & Hydrology, 2021). The main purpose is to develop a framework for assessing impacts of all planned and constructed installations on seabirds and marine mammals in all seasons, over multiple years and at multiple population scales. More specifically, they will develop methods to facilitate a robust assessment of cumulative effects using a consistent and transparent approach. The main deliverables from the project will be a data library, an R package to run the modelling tools, and a user interface that allows non-technical users to generate predicted impacts at a population level for both individual projects and cumulative assessments.

CASE 4

Coordinated environmental monitoring – examples from Belgium and Norway

What: Effective mitigation of project impacts requires a comprehensive understanding of the biodiversity features in an area and how these change over time with regard to OWF development activities. Information derived from monitoring surveys can be used to evaluate the effectiveness of mitigation actions and inform adaptive management to ensure the project is set to meet its biodiversity objectives.

Relevance: Relevant to all OWF projects.

EXAMPLES

Belgium
Within the Belgian part of the North Sea, a zone of 238 km2 is reserved to produce renewable energy and consists of eight operational wind farms. Prior to installing a wind farm in this area, a domain concession and an environmental permit is required. The environmental permit includes terms and conditions intended to minimise and potentially mitigate the project's impact on the marine environment and impose an environmental monitoring programme (Degraer, 2020).

The monitoring programme is agreed between the competent national authorities (Royal Belgian Institute of Natural Sciences), operators and other stakeholders. Operators contribute to a larger fund that is used to monitor the total impact/effect of the activities. The monitoring programme is performed by the Royal Belgian Institute of Natural Sciences through the Belgian OWF environmental monitoring programme (WinMon. BE). The monitoring programme covers both direct impact quantification and cause-effects relationships of selected impacts.

Both authorities and operators are favourable to this solution, as it offers predictability to the operators and flexibility to the government to follow emerging topics and to gain an overall picture of environmental impacts. All data is available to the public on the government's webpages and contributes to trust and transparency of accumulated knowledge.

Experience from coordinated environmental monitoring of petroleum related activity in Norway
Oil and gas companies that operate on the Norwegian continental shelf are required to carry out environmental monitoring to obtain information on the actual and potential environmental impacts of their activities. It also provides authorities with a better basis for regulation.

Requirements for how monitoring and reporting should be performed are outlined in "Guidelines for environmental monitoring of offshore oil and gas activities on the Norwegian continental shelf" (Norwegian Environmental Agency, 2020). The guidelines cover in detail the expected scope of monitoring activities, which parameters must be analysed, which methods must be used, as well as providing requirements on necessary accreditation and templates for reporting. The guidelines were developed through cooperation between the Norwegian Environment Agency, an expert advisory group appointed by the Agency, oil and gas companies, and consultancy firms.

The environmental monitoring aims to document the degree to which an installation or a wider area around an installation or in a region is impacted because of discharges from oil and gas activities. The results from monitoring activities enable verifications of predictions and conclusions from environmental impact assessment studies performed prior to activity start.

The operators develop the environmental monitoring programme, which is presented and discussed at annual meetings with the Norwegian Environment Agency, the Norwegian Oil and Gas Association (NOROG), and other operators. The final programme is approved by the Norwegian Environment Agency.

Results from the previous year's monitoring and plans for future monitoring are presented at an annual forum for offshore environmental monitoring.

Benefits

Efficient use of time and resources as well as building trust and transparency related to accumulated knowledge and facilitating stakeholder dialogue.

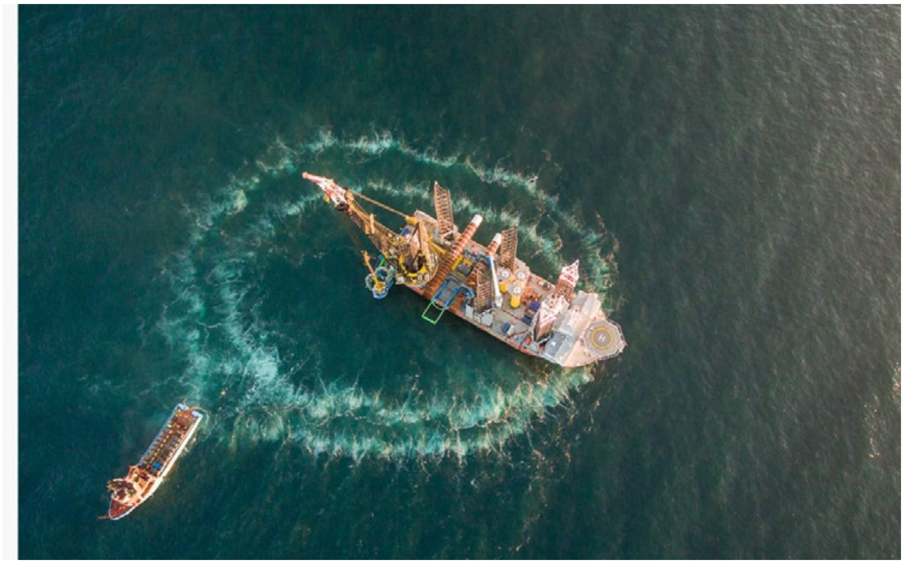
CASE 5

Sound mitigation with bubble curtains in the construction phase

What: During installation of monopiles and jackets at sea, the noise generated by high-energy piling may harm the marine environment. To mitigate the risk of noise for marine life, governments have adopted noise limits for pile-driving operations in their permits for offshore construction projects. To adhere to such noise limits, offshore developers are using air bubble curtains that reduce the sound levels by means of a looped hose on the seabed – pressurised by air compressors – generating a bubble curtain.

Relevance: As noise is the most important acute environmental impact of OWF development projects, this technology is relevant for for all OWF projects.

Process: The technique is widely used to mitigate sound impacts from sub-sea activities, such as piling, in connection with oil & gas development operations, as well as in connection with bridge-building activities. Bubble curtains are also used to mitigate sound impacts from blasting activities during the construction of bridges and tunnels.



Bubble curtains were used to reduce underwater noise during pile driving for the Danish Kriegers Flak offshore wind farm.
Photo: Vattenfall. Sandbank: Bubble curtain – Vattenfall. License.

Bubble curtains have also been thoroughly studied in connection with OWF development. Several different variations of the technique are being deployed today, including double bubble curtains, confined bubble curtains, layered ring systems, vertical hose bubble curtains etc. Studies from Germany (Koschinski, 2013) have concluded that all of these variations are effective noise mitigating techniques, both in practical and experimental examples. The various bubble curtain concepts have different advantages and disadvantages with regard to their noise reduction potential and need to be tailored to specific operations. This is also reflected in studies carried out in Belgium where differences in tidal currents affect the effectiveness of the bubble curtains as a noise mitigating measure (Norro, 2020).

The effectiveness of bubble curtains as a noise mitigating action is shown to be dependent on the distance between the noise generating activity and the bubble curtain, as well as the number of bubble curtains. In a study from Germany, the use of double bubble curtains combined with the use of seal scaring sounds as a warning sound, proved highly effective on reducing impacts on marine mammals, beyond simply adhering to statutory requirements (Dähne, 2017).

Concluding remarks

Experience with, and plans for, OWF development differ among the Nordic countries. Denmark is by far the most experienced country when it comes to wind energy development, with a long tradition of utilising wind power, and is perceived as a model and pioneer in the area. Denmark's existing OWF projects generate approximately 1,700 MW, and there are projects representing 15 GW in planning phases. OWF development is central in the government's investment policy, and the authorities are taking an active role to ensure predictable conditions for all parties involved by taking responsibility for preparing all aspects of project planning and design. Fixed-foundation projects and energy islands are in focus.

Norway has just started a process of OWF development by opening two areas for applications for development, representing a potential of 4.5 GW. In addition to these, the government has approved plans for the development of Hywind Tampen, a floating installation intended to provide electricity to the Snorre and Gullfaks platforms. Upon commissioning, it will be the largest floating wind project in the world.

Due to deep waters in the North Sea, there has been an emphasis on developing floating wind in Norway. The overall policy frameworks are in place, but there is still a need for a detailed regulatory framework for OWF development in Norway. Norway has extensive offshore experience from the O&G industry. For offshore wind, and especially floating wind, to succeed in Nordic environments, the transfer of knowledge, experience and expertise from the oil and gas industry is considered a key factor.

Sweden and Finland have long experience with wind energy onshore and wind energy accounts for about 12 per cent of Sweden's energy production. Swedish OWFs currently produce 190 MW, and there are projects in planning phases equivalent to 2.5 GW. In Finland, OWF projects represent approximately 70 MW. In addition, approximately 3 GW is planned for development. Both countries have major potential to utilise wind energy.

There is less focus on OWF development in Iceland and the Faroe Islands. Currently, Iceland has two active onshore windmills with a connected capacity of 1 MW each, and no OWF. In the Faroe Islands, the municipal power producer and distributer is planning a fixed-foundation OWF with a capacity of 150 MW.

Based on the different levels of experience and background with OWF development among the Nordic countries, there is a potential for beneficial cross-border experience transfer. Policy frameworks differ, but the overall structure will be influenced by EU regulations.

The natural environment in the North Sea and the Baltic Sea is different when it comes to both physical and biological parameters. The North Sea has deeper water and floating wind will be important for development in these areas. In the Baltic Sea, fixed foundations will be more relevant. Both ecosystems are under pressure from anthropogenic impact, however, more species and habitats are affected in the Baltic Sea than in the North Sea. This is much due to the shallow inland conditions and the heavily populated catchment area. Both seas represent busy maritime areas.

OWFs will represent an additional activity in these ecosystems, which already are under pressure, and it is important that development does not cause significant damage to the environment or significant conflict with interested parties. To accommodate biodiversity in Nordic waters, a thorough understanding of the natural environment and other stakeholder activities in the different areas is key, both for current and future plans. This should be based on baseline studies and effective stakeholder engagement.

In this project, we have identified that important mitigation measures for OWF development in the Nordics will be:

- In terms of strategic planning, continuous work on both a holistic and project-specific level to develop management plans, spatial plans, and environmental impact assessments for development areas. Research programmes for understanding cumulative effects at the sea basin level will also be important.
- In the construction phase, mitigation measures to reduce underwater sound.
- In the operation phase, efficient environmental monitoring and transparent platforms for sharing data.

The most important measures to accommodate biodiversity are implemented in the planning phase, and key factors for a successful planning phase are effective stakeholder engagement, relevant and updated data, and knowledge. With these factors established, it will be easier to identify and assess cumulative effects, and there will be more opportunities for habitat enhancement and offsetting measures.

In order to properly understand cumulative impacts, a holistic view should be taken into consideration in marine spatial planning. There is currently no structured framework for collaboration across Nordic countries to accommodate biodiversity impacts or for strategic planning of OWFs. Some collaboration across Baltic nations is organised through Helcom.

One example of an established framework for environmental monitoring at the sea basin level that potentially could include OWF impacts is the Global Ocean Observer System, which coordinates and supports development and joint service production in European maritime regions.

The cases presented in this report have been selected to reflect important mitigation measures relevant for the different phases of OWF projects in a Nordic context. They also reflect on solutions for emerging challenges and knowledge gaps. An overview of the case studies, including a high-level evaluation of how they can serve as inspiration for good practice for the development of OWs in Nordic countries, is provided in Figure 9.

Our overall recommendation to accommodate biodiversity and stakeholder engagement is to:

- Leverage existing Nordic frameworks for data collection and cumulative impact assessments.
- Establish dialogue and multi-national processes for marine spatial planning at the sea basin level to understand and accommodate biodiversity and stakeholders.

Table 2. Overview of case studies with a high-level evaluation of how they can serve as inspiration for good practice for OWF development in the Nordic countries

<table>
<tr><th>Strategic planning process</th><th>Environmental data</th><th>Cumulative impacts</th><th>Underwater noise</th></tr>
<tr><td colspan="4">Stakeholder engagement</td></tr>
<tr><td colspan="2">Danish Process of Opening Areas
Continuous stakeholder process</td><td colspan="2"></td></tr>
<tr><td colspan="2">Hywind Scotland Pilot Park
Continuous stakeholder process</td><td colspan="2">Sound Mitigation by Bubble Curtains Stakeholder trust</td></tr>
<tr><td colspan="4">Coordinated Environmental Monitoring: Examples from Belgium and O&G in Norway Stakeholder involvement, transparency of data trust</td></tr>
<tr><td colspan="4">Research on Cumulative Effects: CEF (Scotland) and MAROS (2021-2025) (Norway) Stakeholder trust</td></tr>
</table>

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Appendix

Figure 2. Status of OWF projects in the Nordics and neighbouring countries, based on bottom-fixed (upper map) and floating technology (Wind Europe, 2021).

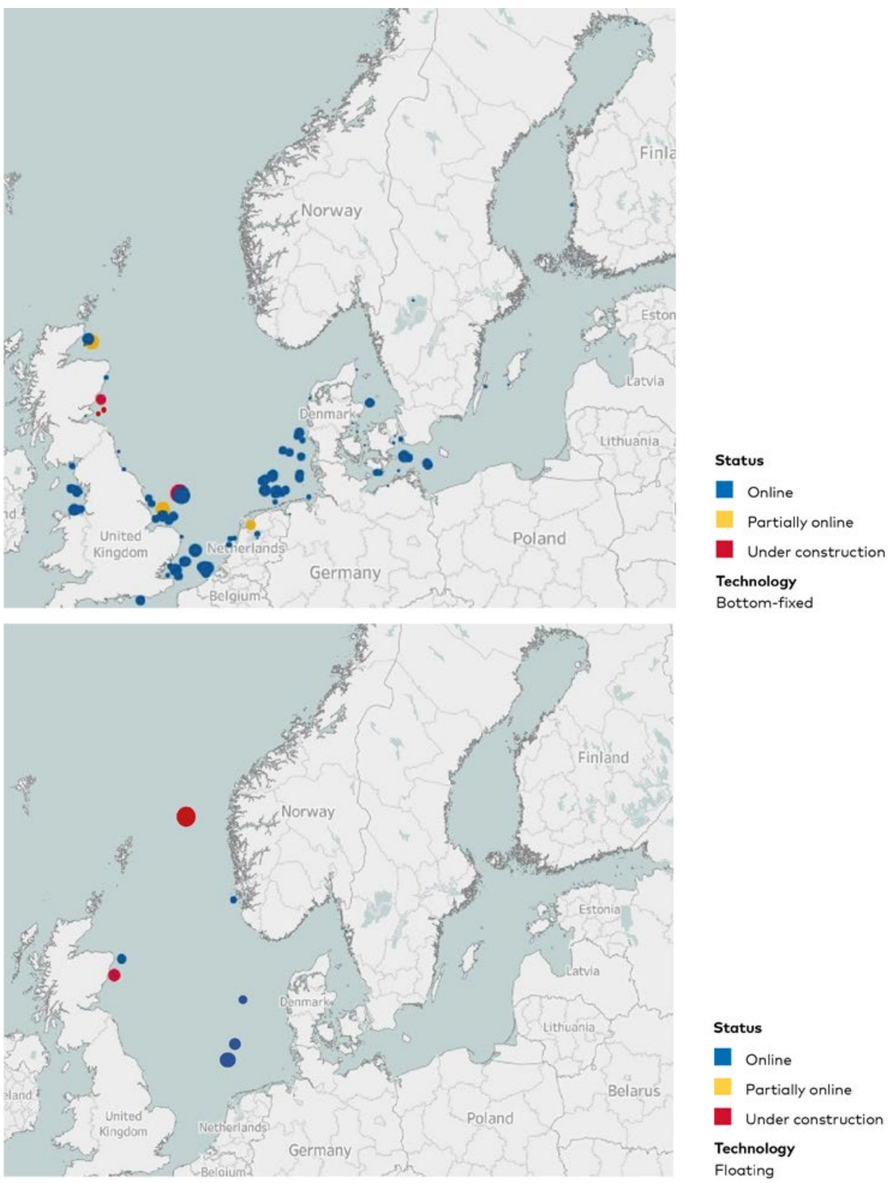


Figure 3. Map of existing OWFs in Denmark (Danish Energy Agency, 2021).

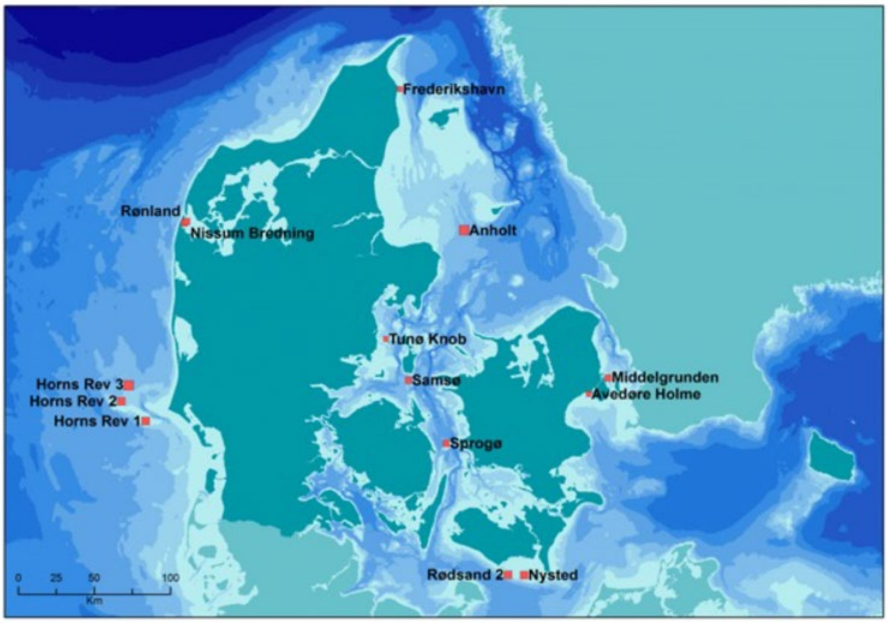


Figure 4. Map of Utsira Nord and Sørlige Nordsjø II. (MPE).

Figure 5. Greater North Sea ecoregion, showing exclusive economic zones, larger offshore Natura 2000 sites, and operational and authorised wind farms (ICES 2020b).

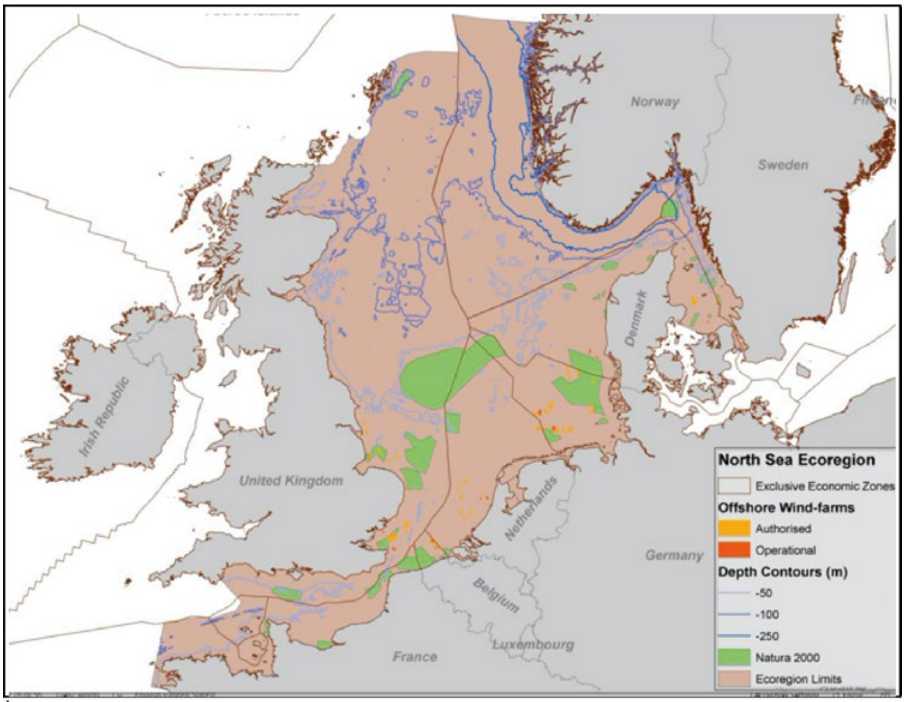


Figure 6. The Baltic Sea ecoregion, showing exclusive economic zones and larger Natura 2000 sites (ICES, 2020a).

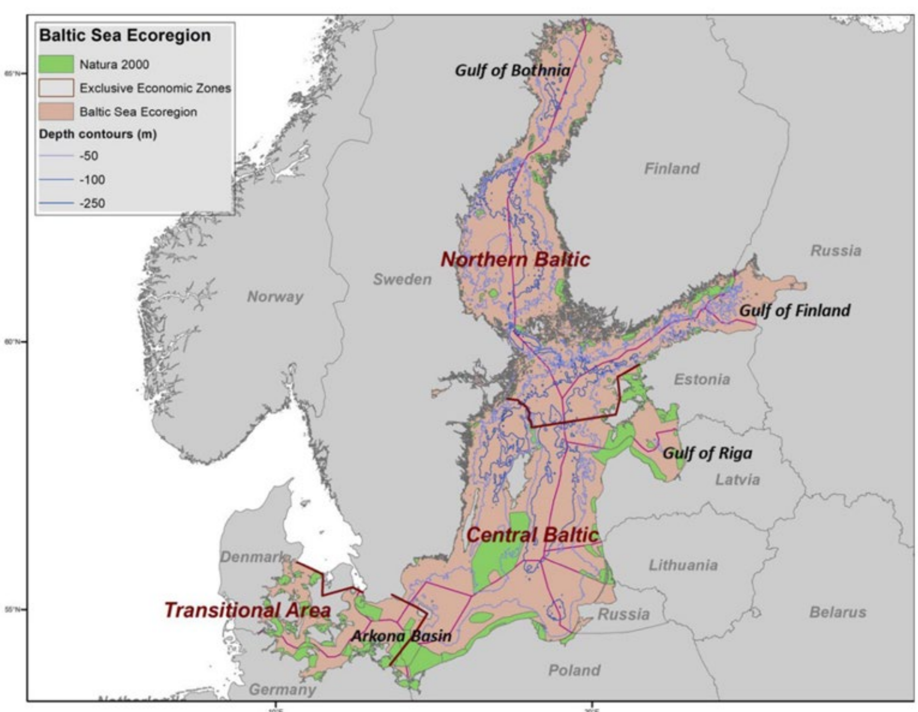
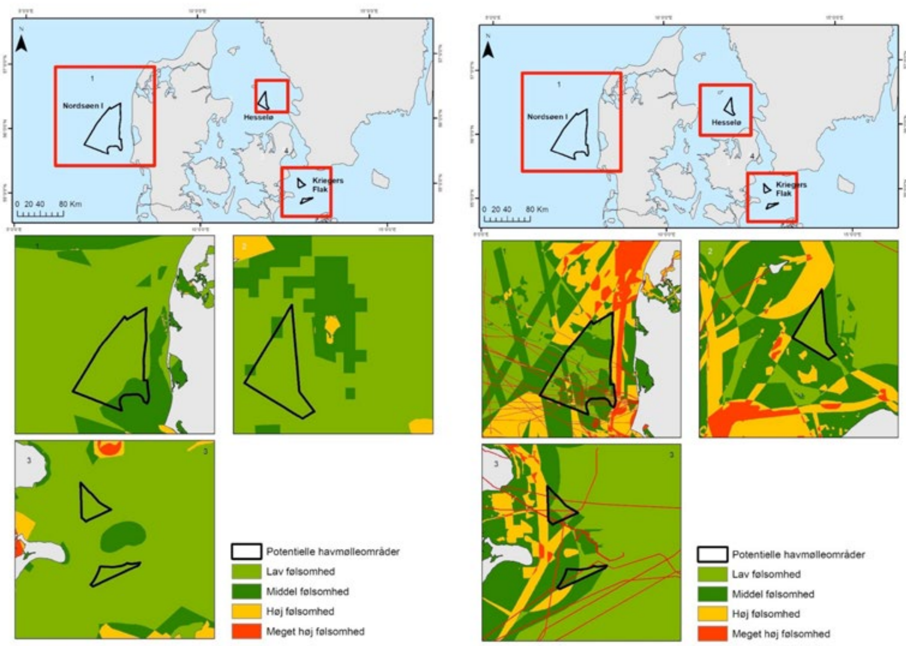


Figure 7. Left: overview of environmental sensitivity for the three areas assessed in the fine-screening process. Right: overview of sensitivity for human impact for the three areas assessed in the fine-screening process (DEA, 2020a).



About this publication

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