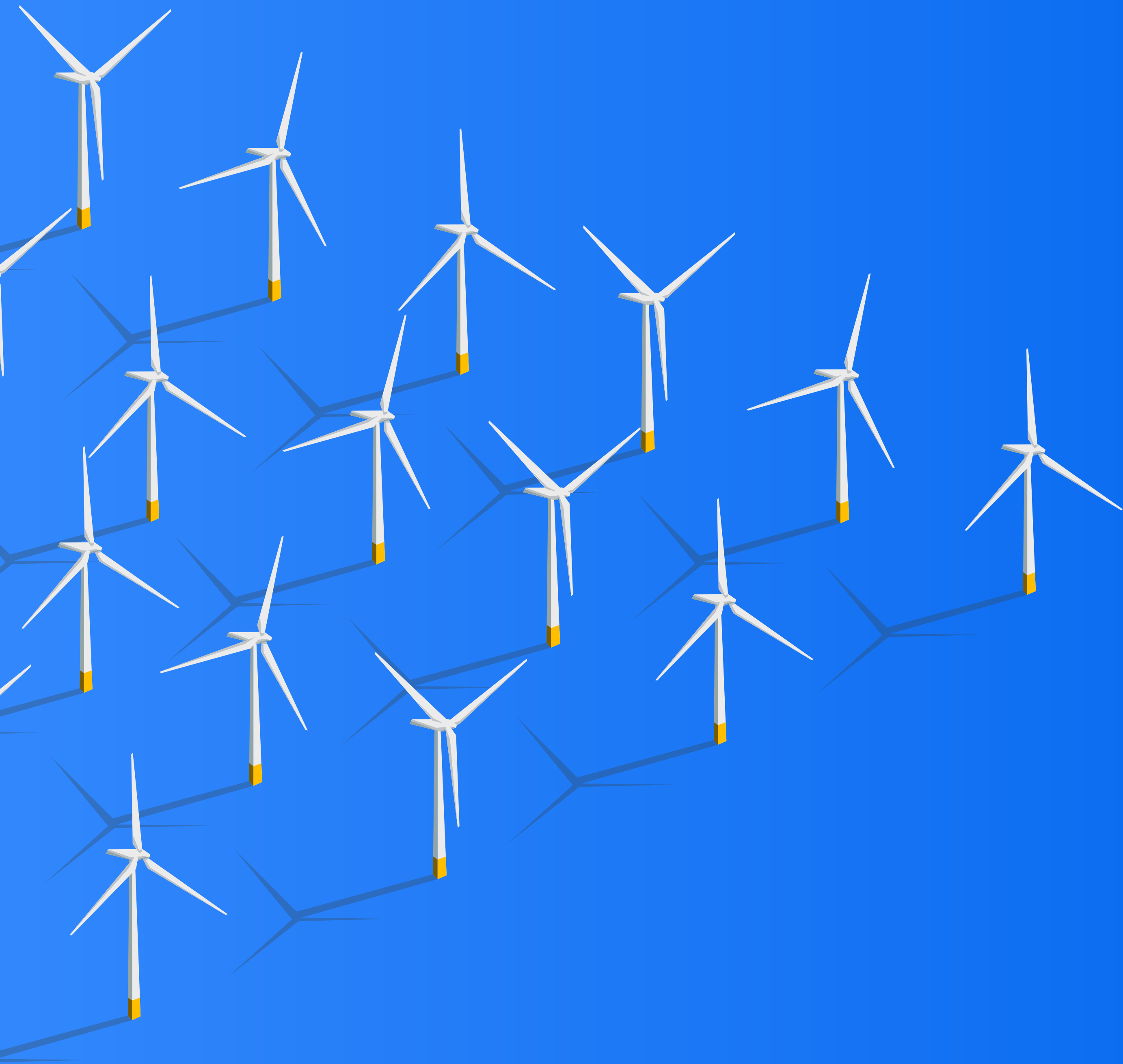

A QUICK GUIDE TO OFFSHORE WIND DEVELOPMENT

OVERCOMING ENGINEERING AND ENVIRONMENTAL CHALLENGES

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FOREWORD

The offshore wind energy era is upon us.

First harnessed more than 30 years ago, the global offshore wind industry is set for dramatic growth. The industry has matured in Europe, while Asia and North America are swiftly taking strides towards their full potential.

Thanks to three decades of hard-earned progress by industry and governmental leaders, 2020 marked a milestone when renewable energy overtook fossil fuels for the first time as the main electricity source in Europe (Ember and Agora Energiewende, 2021).

As part of this energy transition, the United Nation's 2030 Agenda for Sustainable Development represents the world's plan of action for environmental sustainability, social inclusion and economic development. Its Sustainable Development Goal 7 urges countries to ensure access to affordable and clean energy for all by 2030.

Reaching such goals in a timely manner requires international collaboration that promotes sharing best practices related to planning, designing, building and operating an offshore wind farm. As offshore wind markets develop, they're looking at Europe's developed landscape of favourable policies and regulatory programs, advantageous pricing for proven technologies and operational services, and its pool of specialised experts for successful project development.

For us, it's vital that offshore wind projects have easy access to reliable water environment-related data to ensure optimal economic, environmental and social site-specific conditions.

This eBook demonstrates key processes, tools and industry insights for offshore wind developers, operators, investors, as well as government partners, to understand the water-related challenges in offshore wind farm development. The guidance provided in this document is based on **DHI's 30 years of experience in the industry and contribution to more than 85% of all commissioned offshore wind farms worldwide.**

At DHI, we are passionate about developing solutions that solve difficult water challenges. We leverage the latest scientific advancements in water modelling, management and research to help offshore wind farm projects succeed in each phase of development.

Overcoming the barriers to achieve sustainable water management requires cross-sectoral and cross-border collaboration. We know reaching this target won't be easy, but it is possible. And we are here to help.

-DHI

THE UN SUSTAINABLE DEVELOPMENT GOALS AND OFFSHORE WIND

In 2015, 193 United Nations member states signed on to create a shared global development framework based on 17 Sustainable Development Goals (SDGs). To meet this SDG framework, the global offshore wind industry is instrumental.

Sustainable Development Goals related to offshore wind

https://www.un.org/sustainabledevelopment/
The content of this publication has not been approved by the United Nations and does not reflect the views of the United Nations or its officials or Member States

Direct impacts:

Most obviously, the industry can harness a clean, renewable energy source—the wind.

Indirect impacts:

Even indirectly through operations, the entire value chain of an offshore wind project can generate profits, safe employment and economic growth. Governments and civil society partnerships can ensure benefits extend beyond the life of a project, so the entire offshore wind industry can positively impact the natural environment, climate change and social capital too.

This means offshore wind developments will be called on to responsibly locate a project site, use safer processes, incorporate new sustainable technologies, promote the wellbeing of local communities, and enhance environmental stewardship. Each of these efforts, if consciously considered, can be mapped to an SDG target.

While government investment, regulations and planning are essential to achieve the SDGs, other stakeholders also need to understand and sustainably manage water environments for offshore wind development.

This eBook focuses on what developers and operators can do, both alone and in collaboration with other stakeholders, to understand and sustainably manage water environments for offshore wind development. For more detailed SDG guidance within the renewable energy sector, check out the Sustainable Solutions Development Network's Mapping the Renewable Energy Sector Atlas to the Sustainable Development Goals.

OFFSHORE WIND FARM DEVELOPMENT PHASES

Defining the phases of a typical offshore wind project varies by region and regulatory framework.

To explain the interconnected coastal and marine expertise required for each phase, the phases of a project are broadly broken down into the following:

Strategic site selection

↓

Planning and development

↓

Installation and construction

↓

Operations and maintenance

↓

Decommissioning

Both government agency and developer roles, as well as their required input, evolve throughout the phases of an offshore energy project.

For example, government agencies are central in determining offshore wind farm concessions and in the leasing process. Then, they are typically concerned with review and approval in subsequent phases.

Work for developers, on the other hand, typically begins to intensify during leasing and site selection processes. Developers usually experience various peaks of activity in the subsequent phases to reach investment decisions.

From an engineering perspective, each phase requires evaluation of the ambient environment's impact on offshore wind structures. From an environmental perspective, each phase requires evaluation of the impact offshore wind structures have on the ambient environment.

Having accurate, science-based input from marine environment specialists for these phases can make all the difference when it comes to efficient decision-making.

STRATEGIC SITE SELECTION

PHASE 1

In this eBook, 'site selection' refers to the process by which government agencies outline offshore wind farm concessions. It's also when developers determine if, or where, within the concessions a project is viable.

Determining the location and dimensions of a concession is carried out via a master planning process. Or, for developers, it includes various iterations of 'scoping' at different levels of analysis and decision-making.

Depending on your position as a developer or government agency, the goal is to:

- Determine if an area or specific site has a financially viable wind resource
- Determine the engineering solution type for the specific site
- Determine if an area or specific site is environmentally feasible
- Determine the tools and data required to assess conditions throughout a wind farm's life cycle
- Submit and obtain approval of a site assessment plan (SAP) either before or after a site is selected

Many governments and developers choose to work with specialists and consultants to complete these varied and complex tasks more efficiently. Whether for master planning or scoping, there is a need to investigate many environmental and economic variables unique to each area.

DE-RISKING CRITICAL DEVELOPMENT DECISIONS

Appropriate spatial planning and data analyses are essential to limit a project's potential negative impacts and to meet regulations. The use of numerical and data-driven modelling for atmosphere and water, in combination with environmental surveys, is inevitable in the modern site selection process.

The methods, data and modelling tools outlined in this eBook can help identify potential impacts early to ease approval processes, as well as reduce rescheduling and investment risks.

For example, various modules in the MIKE 21/3 software suite are used to assess both the engineering and environmental challenges in each project development stage. When used optimally, such software helps identify the most cost-effective construction and design approaches with the smallest environmental impact.

Tools like ABM-Lab and MIKE Underwater Acoustic Simulator (UAS) are used to simulate the dynamic behaviour of marine life and their interactions with the environment. MIKE 3 Wave FM simulates extreme wave kinematics for evaluating impact loads and structure responses, and model seabed behaviour in close proximity to foundation structures.

Investing in and establishing area-specific models early means these models can more easily be adjusted for analyses and tasks in subsequent phases to save time and money.

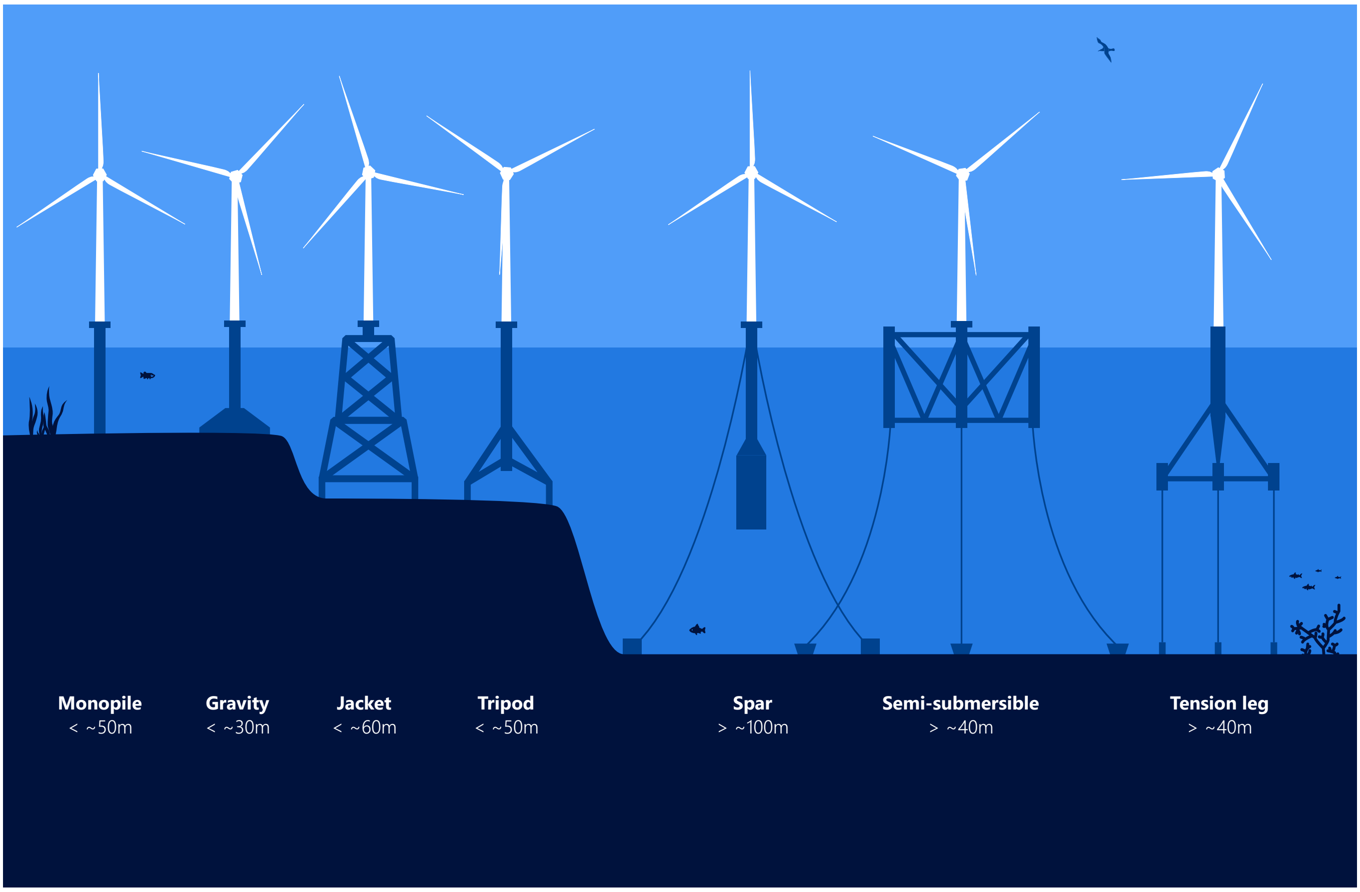
ASSESS INITIAL METOCEAN CONDITIONS

Metocean factors comprise weather (meteorology) and sea (oceanography) conditions. To ensure structural integrity and safe operations, it's vital to adopt systems that match the conditions at the development site. To learn more, read the Metocean Procedures Guide for Offshore Renewables published by the Institute of Marine Engineering, Science & Technology (IMarEST).

Tools like the global MetOcean Data Portal can accurately map and provide comprehensive site-specific metocean data to help understand sea state conditions, site workability and design criteria around potential offshore wind installations. Obtaining such information in the site selection phase goes a long way in reducing risks—and in saving capital and operational expenses.

Make a good foundation!

By using customised tools and high-quality data in the strategic site selection phase, you can use them throughout each phase of the offshore life cycle to optimise operations and de-risk the entire project. Think of the long-term ROI!



Example of typical foundation types and applicable water depths

ASSESS ENVIRONMENTAL SENSITIVITY

To assess the environmental sensitivity of a potential site, it's important to detect mobile marine species and identify the environmental conditions that influence their movements. However, this is difficult due to the wide-ranging, patchy distributions of marine mammals and seabirds.

Luckily, dynamic habitat modelling can identify environmental variables, like currents, that affect marine animal movement. These models produce habitat suitability maps showing potential marine animal hot-spots, sensitive areas and other important zones. On top of that, agent-based models can generate detailed maps of marine animal movements and distribution in and around a potential wind farm area.

Regulators, potential developers and other stakeholders can access such resulting data via the Marine Animal Movement Portal (MAMP), an ideal platform to identify environmentally suitable areas for wind farm development.

UNDERTAKE ENVIRONMENTAL SURVEYS

Environmental surveys provide the necessary input for habitat and animal movement models mentioned above. These surveys are often used by respective regulatory bodies for ecological mapping and siting decisions.

The most important surveys to undertake in this phase include:

- Passive acoustic monitoring to assess occurrence and habitat use of marine mammals and fish on a 24-hour basis
- **Noise monitoring** to assess baseline ambient noise levels in sea regions before a project commences
- **Visual surveys** by airplanes and ships to assess the distribution and abundance of key species such as seabirds and marine mammals
- **Metocean monitoring** to provide, compare and validate numerical models using long-term (40+ years) site-specific wind data and sea state parameters, such as waves and currents, to ensure optimal weather conditions and bankability
- **Other surveys** may include geotechnical, shallow hazards, archaeological resources, geological surveys and biological surveys

PLANNING AND DEVELOPMENT

PHASE 2

Before starting construction, a potential project needs to undergo a planning and development phase.

This phase requires formal applications and approval procedures by local, national and/or international governing bodies. The three main goals of this phase are to:

- Complete plans and engineering designs, including for related port facilities
- Secure planning consents and ensure a project is economically feasible
- De-risk critical development decisions

Planning and approval at the project site-level

To build and operate a wind farm, approval authorities worldwide require accurate data, analyses and formal plans. These requirements must cover both the environmental aspects of development, as well as engineering and design aspects.

Stakeholder engagement can also be required to approve a plan for a specific lease. Stakeholders with significant perspectives on project-related geological, environmental, biological, archaeological and socioeconomic issues can affect potential leasing and development.

ENGINEERING AND DESIGN

If the design of an offshore wind project is poorly matched to its potential location, it may affect its installation, reliability, maintenance and survival. So before starting to plan an offshore installation, you need in-depth knowledge and understanding of a site's specific conditions.

To establish safe and cost-effective environmental design criteria, one must rely on proven technology, accurate data and strong metocean engineering expertise.

If conditional assessments were completed in a project's site selection phase, the same site-specific data and tools can be applied for this pre-construction phase. With these tools, you can run analytical/empirical models, physical models, numerical models and analyse field data.

You'll need to (1) establish environmental design criteria, (2) analyse loads and responses, (3) analyse scour and seabed mobility, and (4) optimise ports as offshore wind supply hubs.

Establish environmental design criteria

Offshore wind infrastructure is often subject to harsh environmental conditions, so it's vital to take design criteria seriously. Many projects now deploy numerical models coupled with site-specific metocean data, using means like the MetOcean Data Portal to assess design criteria. These numerical models and statistical methods are advanced enough to provide an understanding of the effects of complex physical phenomena (like cyclones, typhoons, etc.) on offshore designs

Collaborating with specialised, reputable experts may secure a quick and smooth process to build offshore sites faster, smarter and at a lower cost. Such experts employ validated measurement campaigns developed from appropriate datasets and calibrated instruments to closely work with certifying bodies and developers.

Analyse loads and responses

Regardless of whether your installation has a fixed or floating foundation, loads and response analyses are critical to ensure it can safely withstand the conditions at a given site.

Wind turbine foundations face environmental conditions which complicate the loads and response assessments used to guide optimised design standards. Due to the complexity and magnitude of environmental loads, support structures may need to become heavier and material consumption may need to be increased.

The design basis of offshore wind turbine foundations is often based on historical data and extremal analyses, but present and future trends demand more sophisticated probabilistic approaches to either extend the design life or decrease the total cost of structures over their lifetime.

For this phase, physical-, numerical- and data-driven modelling should aim to describe loads and responses of structures in relation to environmental conditions for both short- and longer timespans. The modules of MIKE 21/3 and Computational Fluid Dynamics (CFD) are perfect for such complex data and modelling.

MIKE 21/3 model of hydrodynamic conditions in the Thames Estuary

Design and optimise ports as supply hubs

To establish a reliable supply chain for installing, operating and maintaining an offshore wind project, respective ports require metocean-related design, engineering plans and approval.

Port development elements requiring marine-related monitoring and analyses include:

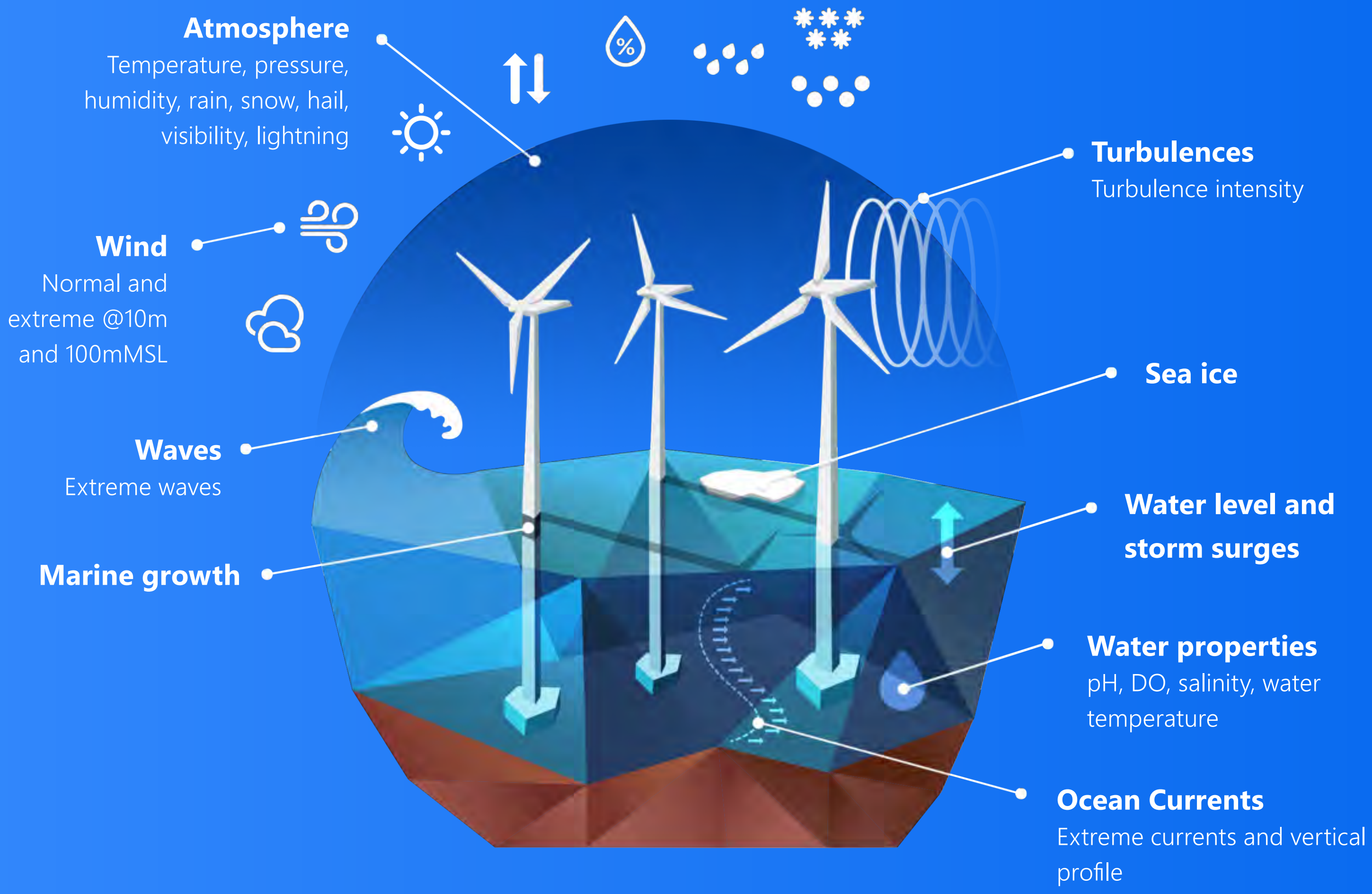
- Port layout plans
- Operational and smart port systems
- Environmental studies
- Hindcast and forecast metocean data
- Water-structure and structure-to-structure interaction
- Vessel navigation and responses
- Coastal and marine siltation predictions
- Capital and maintenance dredging
- Scour and scour protection measures
- Breakwater stability, design and loads on structures

Analyse scour, seabed mobility and mitigation options

Scour is a physical process related to seabed sediment movement due to water flowing around structures. As the installation of an offshore structure on the seabed may induce scouring, there is a need to perform specific scour assessments relating to foundation structures, as well as inter-array and export cables.

To make robust predictions of future seabed levels at wind turbine locations and cable routes, use historical surveys, as well as satellite, geotechnical and geology data in combination with sediment transport models. Or make thorough analyses to protect assets using the DHI Scour Calculator, Computational Fluid Dynamics (CFD) and physical model testing.

World-famous tools, like MIKE 21/3 in combination with satellite imagery, are heavily used to model and evaluate the stability of the seabed over the lifetime of a wind farm. This includes general seabed levels and the possible impacts of migrating bed forms on offshore wind farm structures and secondary structures.



Metocean conditions to consider for offshore wind development

ENVIRONMENTAL CONSENT

Approval for an offshore wind farm project is based on environmental impact assessments (EIA) and consultations with various stakeholders. The consultation process includes planners, regulators, experts, the public and others, culminating in an Environmental Impact Statement (EIS).

The EIS generally describes the local environment, the development itself, assessments of its possible effects, and proposed mitigation strategies for significant environmental impacts.

Regulators then examine the EIS and decide whether the residual effects are permissible. If consent is granted, it may come with conditions to ensure further mitigation measures are employed.

To meet environmental regulations and ensure best practices, projects may be required to adopt, or should consider adopting a comprehensive environmental monitoring and management plan (EMMP). An EMMP validates EIA analyses and helps better manage construction and operational impacts.

Environmental resources to assess

Environmental impact assessments for offshore sites can be more complicated than onshore sites because their impacts, processes and components span both coastal and marine ecosystems. To develop a truly sustainable wind farm, it's imperative to determine its potential impacts to life underwater, in the air and on land (see graphic on the next page).

Get your environmental impact assessments in place!

DHI can help monitor environmental impacts throughout a wind farm's entire life cycle so you can protect the environment and get quicker development approvals.

Tools for offshore environmental impact assessments

Baseline studies are key to conduct environmental assessments. There are several smart tools and practices that can help practitioners better collect and understand data required for an offshore wind project's water-related EIA. These include:

- Methods like passive acoustic monitoring and visual surveys from airplanes and ships are perfect to identify the occurrence and habitat usage of marine mammals
- MIKE Underwater Acoustic Simulator (UAS) can be used to model the reach of underwater noises caused from development activities. Combining MIKE UAS with dynamic habitat modelling can help investigate the number of marine animals within the noise range and their reactions to it
- Sediment plume modelling and scour assessment tools can support other impact analyses

Regional responsibilities

The potential effects of offshore wind farms differ by regional regulations and species type. Specific regions require specific studies for certain species depending on their occurrence and protection status. Other species have specialised analyses depending on their likelihood of interaction with the structures, sensitivities and avoidance responses.

By conducting environmental impact assessments and monitoring, developers and operators can make decisions knowing all the environmental consequences of their actions. Moreover, they can guide appropriate actions to protect, restore and enhance the environment.

GUIDANCE FOR IMPACT ASSESSMENT

Component	Examples of what to analyse
Water quality	• Generated sediment plumes (e.g., from trenching activities) • Release of pollutants from mobilised sediments (sediment plumes) • Release of pollutants from operation vessels, equipment and/or materials
Underwater sound	• Changes in the underwater soundscape caused by construction activities (e.g., piling)
Benthos	• Direct impact from anchor drag • Influences of any altered seafloor morphology • Habitat and community population changes associated with the artificial reef effect (i.e., benthos on turbine foundations)
Fish	• Influence of relevant pressures (e.g., altered oceanographic conditions, underwater noise, changes in water quality, electromagnetic fields) • Changes to habitats, distribution and associated community populations • Focus on threatened, endangered or commercially relevant species
Birds	• Changes in resting, foraging and moulting patterns • Collision risk with wind turbines • Migratory and protected species
Marine mammals	• Relevant pressures (e.g., underwater noise, vessel strike risk) • Changes in the amount and distribution of species, particularly protected ones
Cultural & archaeological resources	• Disturbance or loss of archaeological sources due to project development
Social and economic activities	• Influence on recreational or commercial fisheries • Effects to coastal recreational activities • Disturbance to the visual horizon
Coastal safety	• Shipping safety • Coastal communities' property and infrastructure

INSTALLATION AND CONSTRUCTION

PHASE 3

After a project gets approved and the final investment decision is made, a series of activities take place to prepare a site and to manufacture components for installation.

The installation timeframe of project varies depending on the development size, construction season, vessel capability and availability.

This phase includes preparing and installing foundation structures, turbines and transformer stations, as well as final testing and commissioning. Installation of inter-array cables, export cables and construction of substations also take place in this phase.

Construction and operations planning

Depending on your region's regulations, this phase may require submission and approval of a Construction and Operations Plan (COP). A COP describes all proposed activities on a lease area and must include data and results from surveys. It must also provide the analysis of direct and indirect environmental and socioeconomic effects resulting from the project.

Due to the difficult nature of offshore environments, some construction and pre-commissioning activities are performed onshore and later transported to a site for installation to minimise safety and financial risks.

Metocean forecasting for installation and construction activities

Construction can't take place unless meteorological and oceanic conditions are suitable. If operating tasks are poorly matched to the operating environment, certain tasks may suffer significant delays.

Many installation and construction tasks require safe weather conditions for a stretch of a few days to successfully complete. To conduct both survey and access activities, vessels and aircrafts require suitable conditions on arrival—otherwise their mission may have to be aborted causing delays and considerable financial costs.

To prevent such delays and save costs, such missions can be planned for using effective forecasting tools, like Metocean Risk Ops. This tool can:

- Integrate metocean data with practical risk measures derived from vessel motions for short-term forecast planning and seasonal analyses
- Couple site-specific forecasts with hindcasts statistics to determine forecast uncertainty and de-risking information
- Send alerts in the event of rapid, significant condition changes so mitigation actions can be taken for personnel, operations and equipment
- Provide on-site forecasts for critical operations to monitor conditions and provide updates

Metocean and environmental monitoring

Data collection continues throughout a wind farm's installation and construction phase for better forecasting capabilities and operational decision-making. Considering the cost of data collection, and the important decisions it can inform, data collection campaigns should be designed and managed by competent specialists who understand how to use and present the data effectively to decision-makers.

Most importantly, such data must be analysed to put operators' safety first when conducting high-risk tasks like boarding an offshore wind structure from a vessel. The ability to correctly predict local wind, wave and current conditions for safe access is crucial.

Smart vessel planning for installation and construction

Installation and construction strategies should include smart vessel planning throughout the project's life to ensure safe personnel transfer. Vessels should match the demands of a project, its location and phase of development.

For instance, construction-related vessels are only required for a few days. This means long-term charters are less likely to be used throughout the construction phase. Vessels of opportunity may be adopted for specific operations and maintenance access tasks to support a project.

Recording vessel movements and metocean conditions during operations can also provide valuable information for operators and owners in the subsequent development phases too. Not only does such a data combination save considerable operations and maintenance activity costs, but it also helps a project reach its ultimate goal of producing as much power at a time as possible.

Noise monitoring during installation and construction

Several countries require monitoring of construction noise to validate the impact assessment and/or to verify compliance with marine life noise criteria. Noise mitigation measures are often applied to reduce the impact of underwater noise.

Mitigation measures can include engineering solutions that make the sound sources quieter. Measures can involve creating sound barriers—like air bubble curtains—around a turbine pile-driving site. Specific sounds can also be produced to result in marine mammals leaving the immediate zone of danger before construction activities start.

Ensure the best metocean data!
High-quality, site-specific metocean data at your fingertips can help you react swiftly to unforeseen impacts during the installation and construction phase.

Marine species monitoring and installation management

When managing marine habitats during this phase of an offshore wind development, having a digital Marine Animal Movement Portal (MAMP) can help generate detailed maps of mobile marine animal species movements and distribution in and around a wind farm site.

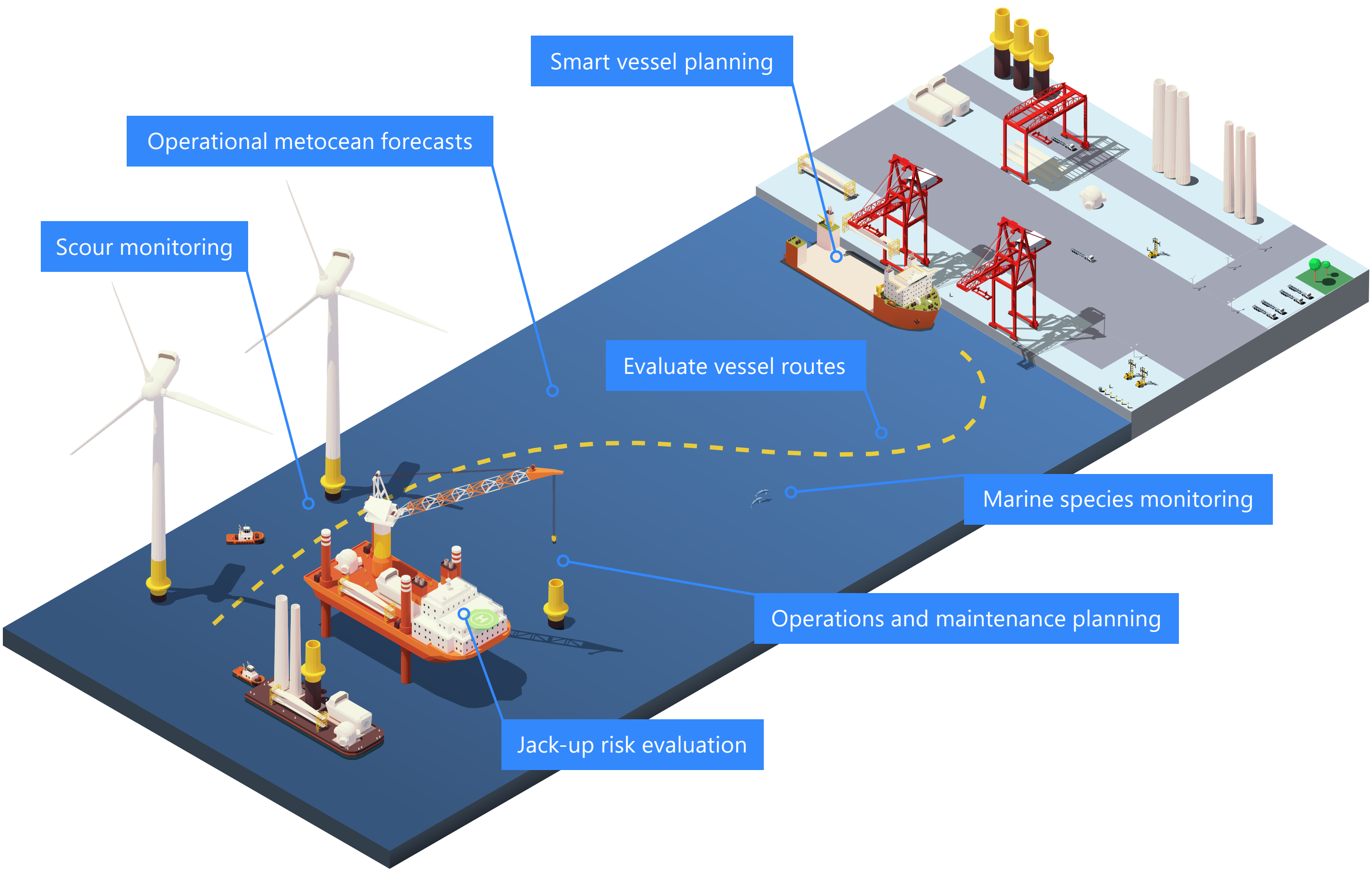
OPERATIONS AND MAINTENANCE

PHASE 4

Wind farms require maintenance throughout their typical operational life of 20-25 years. Successful projects have a data-backed operations and maintenance (O&M) strategy that includes preventive and reactive maintenance actions.

A robust O&M strategy is essential for both owners and operators to:

- React when required to minimise risks during the O&M phase
- Minimise project downtime to reach and maintain targeted availability
- Support both revenue generation and cost management
- Avoid and minimise impacts to natural and socioeconomic resources
- Fulfil mitigation commitments and permits/ approvals
- Synergise the interdependences of offshore wind farms and ports

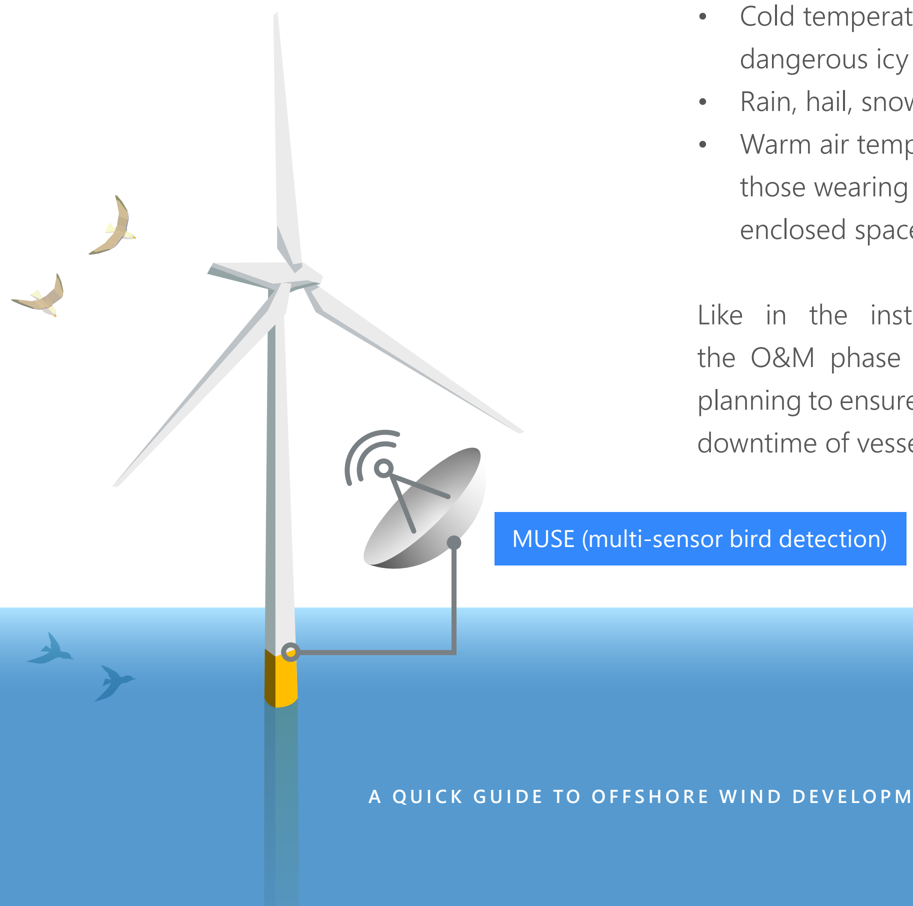


Operations and maintenance tasks

Post construction environmental monitoring

Monitoring is developed based on project and site-specific considerations. While there is not an inclusive list of all possible monitoring scenarios, below lists some prominent tools used throughout the industry:

- MUSE (multi-sensor bird detection) combines radar technology with cameras to monitor seabirds and migrating birds in a project area 24/7. This system helps provide reliable, cost-effective risk management of bird collisions rather than solely relying on human observation
- Passive acoustic monitoring keeps track of marine mammal and fish activities during operation



Operational metocean forecasts

O&M is typically managed locally, 24-hours a day to assist with reaction times. For smart operations management, an overall O&M activity schedule can be developed to calculate weather downtimes.

Never underestimate the power of the sea—or winds. Unsuitable offshore operating conditions can expose people to risks of injury and death. Offshore conditions can change rapidly, so procedures should be in place to cope with foreseeable changes.

Digital solutions like Metocean Risk Ops help collect and analyse data to apply to an O&M strategy to ensure the highest levels of safety during O&M tasks. An O&M strategy should describe actions based on weather window durations, wave heights, wind speeds and current speeds.

The O&M phase is particularly sensitive, as tasks involving personnel transfer onto offshore structures requires suitable weather conditions for vessels and access systems. In addition to wind, wave and tidal conditions, these other risks need to be considered:

- Lightning can be a hazard to people on offshore structures
- Cold temperatures can cause hypothermia and dangerous icy surfaces
- Rain, hail, snow and fog can affect visibility
- Warm air temperatures can cause heat stress for those wearing a survival suit or working in hot enclosed spaces

Like in the installation and construction phase, the O&M phase requires smart vessel and aircraft planning to ensure safe personnel transfer and reduce downtime of vessels waiting for bad weather to clear.

Scour monitoring

Just as when planning a project's engineering and design, scour should be monitored and assessed during the O&M phase. Particularly, such tasks should be conducted around unprotected foundations, jacked-up installation vessels and vessels with legs on the seabed.

Scour and punch-through risks need to be mitigated. To determine which mitigations activities to pursue and make accurate scour-related analyses that can protect assets, use the DHI Scour Calculator and Computational Fluid Dynamics (CFD).

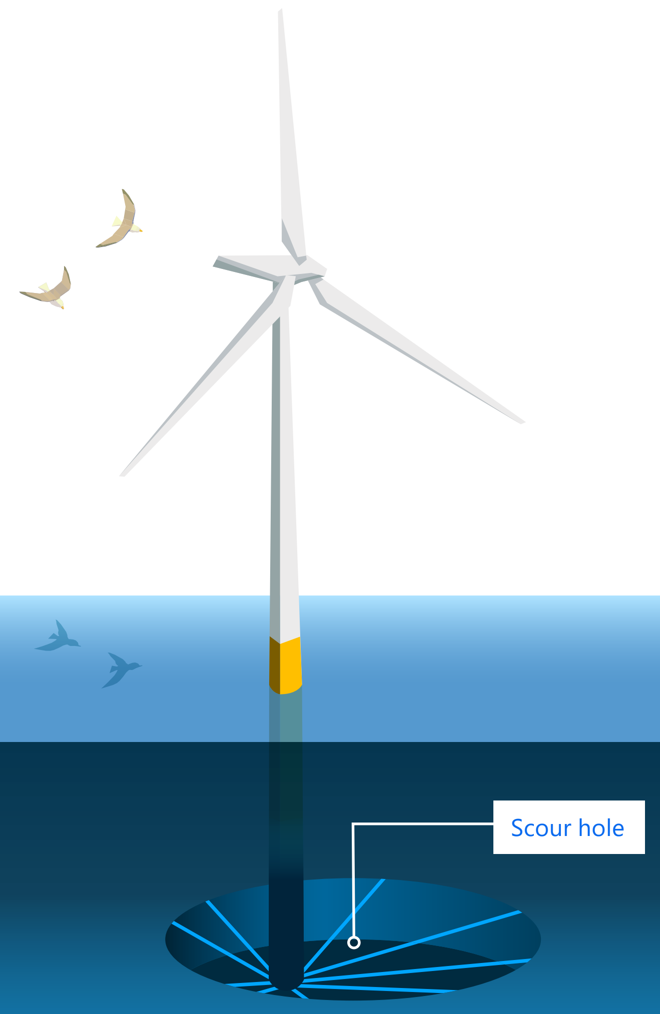
Consider life extension

Offshore wind farm lifespans are based on technical design considerations, commercial factors and legal arrangements including leases, licencses and consents. It is important that integrity is assured to extend a project's operational life. To support the commercial business case for life extension (or re-powering), a robust assessment of a project's assets is required.

To do this, data from over a project's lifetime is combined with an asset integrity analysis. Collaborating with specialised, reputable experts can help with specific water environment monitoring tools and data for offshore life extension and decommissioning tasks.

Get the right people for the right support!

Now that your offshore wind farm is up and running, now what? Ensure you link up with industry experts to ensure safe and efficient O&M, as well as plan for potential wind farm life extension.



DECOMMISSIONING

PHASE 5

Offshore wind farm assets that have been in service beyond their design life—or their extended life—need to be decommissioned safely and economically. Many of the decommissioning phase's processes are like the installation phase's processes, but in reverse.

Decommissioning activities need to be in accordance with initial permit conditions for the project. Appropriately, this includes conducting an environmental impact assessment of decommissioning plans for the environmentally neutral removal of offshore substructures and foundations, as well as their transportation to shore.

It's important for a project's site to be left in a similar condition as it was before the project existed. Decommissioning requirements, however, are unique to each site depending on structure type, equipment, natural conditions, regional regulations and more. Also, there is a broad discussion among regulators about leaving the subsurface structures in the sea because they can embody artificial reefs.

So be sure to consult with an industry expert to take the right steps for your project.

HOW DATA AND MODELLING CAN HELP DECOMMISSIONING TASKS

Decommissioning environmental impact assessments

Decommissioning environmental impact assessments are like the ones described in the environmental consent section. Similar tools—like the MIKE Underwater Acoustic Simulation (UAS)—are used to conduct numerical modelling and assess impacts from decommissioning activities. As such, operational metocean forecasts and smart vessel planning will also have to be organised.

There are tools like MOOD Decom, an operational cloud-based system, that provides high-quality metocean information to support decommissioning activities like:

- Quantifying uncertainties
- Integrating probabilistic measures of workability
- Monitoring near-real-time environmental impacts
- Forecasting and hindcasting

Accurate metocean information and translation into practical risk measures are the keys to developing reliable workability assessment that ensure cost-efficiency and provide safer, compliant operations.

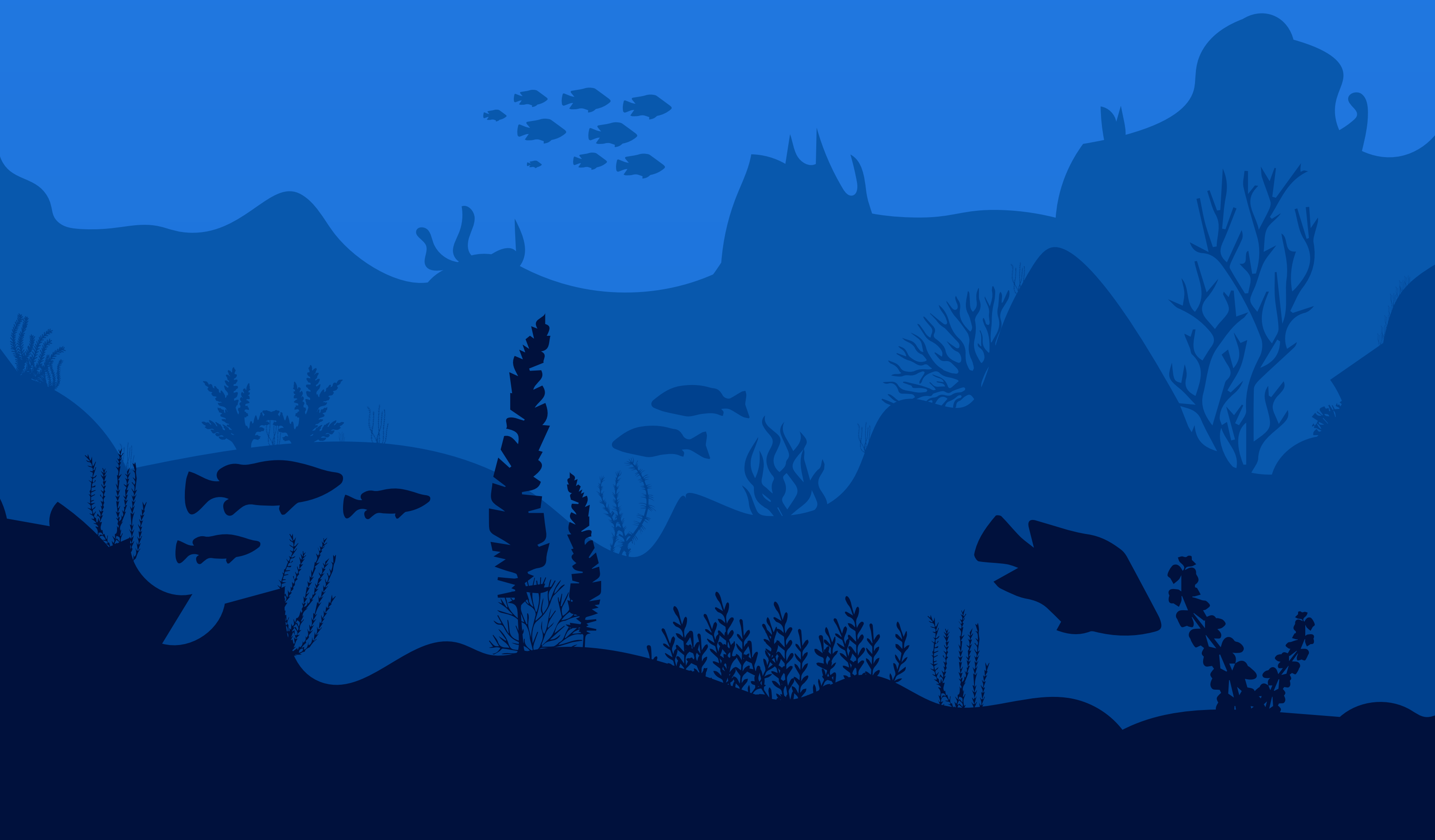
SUSTAINABLE MANAGEMENT OF WATER-RELATED CHALLENGES

Offshore wind is one of the world's fasting growing energy sources, with no signs of stopping in the coming decades.

While cost and scalability are key considerations for a project's success, it's also vital to consider sustainable operations in and management of water environments. Each renewable energy project should map out how it can align with and support the UN's Sustainable Development Goals.

Moreover, understanding an offshore wind project's major water environment-related processes, barriers and solutions for each phase can help developers pass consent regimes and help operators maintain safe, productive service levels.

Managing the water environments of offshore wind farms can be complicated, but it doesn't have to be. There are plenty of specialty tools and expertise available, as demonstrated in this eBook to get you started. The following case stories provide further examples of typical offshore wind farm water-environment related challenges and solutions.



REAL-WORLD SOLUTIONS

Poland advances in renewable energy approvals while protecting marine life

Poland has ambitious renewable energy plans to battle climate change. The country got its first ever offshore wind farm approved thanks to cutting-edge noise, habitat and collision risk modelling that fostered the protection of harbour porpoises and birds.

Challenge

For project approval, environmental impact assessments (EIAs) must be completed to identify and overcome uncertainties. This project's environmental challenges include life below and above the sea. These waters are home to the endangered Baltic harbour porpoise, which can be harmed by construction noise. Moreover, local seabirds can be displaced, and migratory birds can collide with the rotating turbines blades.

Solution

- Underwater Acoustic Simulator proved porpoise impacts could be minimised with noise mitigation measures.
- Dynamic habitat modelling enabled extrapolations about the distribution of seabirds and increased EIA reliability.
- Collision risk modelling provided accurate data of birds at risk of collision with wind turbines.

Reduced uncertainty of project impacts

Identified the best value for money approach for noise mitigation

Approval for the first of many offshore wind farms in Poland

'MEWO has successfully cooperated with DHI for over eight years implementing offshore wind farm projects in Poland. DHI's reliable analyses and reports on marine mammals, seabirds, migratory birds and underwater noise modelling has supported us with the best solutions. Their professional team considers the latest methods used around the world, provides guaranteed performance, and seamlessly communicates with us every step of the way. We look forward to our continued cooperation.'

-Michał Sandar, Project Manager Deputy Director of Operations MEWO. S.A. (Subsea Solutions)

REAL-WORLD SOLUTIONS

Innovative design lowers costs of offshore wind farm scour protection systems by 30%

Today, scour protection for wind turbine foundations makes up a considerable part of the installation cost. Vattenfall's decision to use a new approach for Denmark's largest offshore wind farm paid off when it resulted in significant cost savings.

Challenge

The presence of a monopile in a marine environment changes the flow pattern in its immediate area, resulting in increased local sediment transport. This causes scouring of the seabed around the monopile—a serious risk that may compromise the stability of the wind turbine foundation. In addition, the cables on the seabed may risk exposure due to the eroded seabed around the monopile.

Solution

- Single-layer scour protection approach applied instead of the traditional two-layer solution
- Wide-graded rock material encompassing both filter and armour effect installed in one step
- Total installation procedure reduced from three to two steps

30% cost savings due to optimised scour protection design

Installation steps reduced from three to two

Chance to apply new R&D in the planning and design phase

'DHI and LIC Engineering designed the application of wide-graded rock as an innovative solution for scour protection systems, and this has shown to be a viable design option with great potential for cost savings.'

-Victoria Ruiz Gomez, Project Manager, Offshore Foundations, Vattenfall

REAL-WORLD SOLUTIONS

MetOcean Data Portal sets up success for Dutch offshore wind development

The Netherlands' offshore wind capacity is expected to total 11 GW by 2030. This is, in part, thanks to the delivery of the world's first certified digital database encompassing 40+ years of high-quality metocean data. Now, developers have a basis to design, operate and maintain new and future offshore wind farms in Dutch waters.

Challenge

The Netherlands Enterprise Agency, on behalf of the Dutch Government, needed to provide developers with easy access to consistent, reliable and high-quality metocean data. Such data are fundamental to successfully design, operate and maintain an offshore wind farm.

Solution

- Create a user-friendly database for 40+ years of modelling results (including both time series and 2D spectral data)
- Have a data portal that presents normal and extreme conditions at sea
- Use only top-quality data, validated against multiple measurements

No further metocean studies needed, resulting in reduced cost

Provided access to certified, high quality metocean data

Set basis for future offshore wind developments

'We challenged DHI to provide a world-class metocean database to allow developers to optimise their designs in the tender stage. DHI exceeded our expectations.'

-Ben de Sonneville, Senior Consultant, BLIX Consultancy BV (on behalf of the client RVO.nl)

ABOUT DHI

DHI is a leading innovative, global advisory company that integrates deep domain knowledge with advanced digital technology to enable new ways to manage, protect and live with water and water-related ecosystems.

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A QUICK GUIDE TO OFFSHORE WIND DEVELOPMENT:
Overcoming engineering and environmental challenges

Published as an eBook, available at:
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REFERENCES

Agora Energiewende and Ember (2021): The European Power Sector in 2020: Up-to-Date Analysis on the Electricity Transition. https://ember-climate.org/wp-content/uploads/2021/01/Report-European-Power-Sector-in-2020.pdf

Bailey, H., Brookes, K. L., & Thompson, P. M. (2014). Assessing environmental impacts of offshore wind farms: lessons learned and recommendations for the future. Aquatic Biosystems. https://www.nrc.gov/docs/ML1434/ML14345A578.pdf

Brown et al., 2018. Metocean Procedures Guide for Offshore Renewables. https://www.imarest.org/reports/650-metocean-procedures-guide/file

Bundesamt fuer Seeschifffahrt und Hydrographie (BSH, 2013). Standard - Investigation of the Impact of Offshore Wind Turbines on the Marine Environment (StUK 4). Standard-Investigation-impacts-offshore-wind-turbines-marine-environment_en.pdf (bsh.de)

The Danish Energy Authority. (2006). Offshore Wind Farms and the Environment Danish Experiences from Horns Rev and Nysted. Danish Energy Authority. https://tethys.pnnl.gov/sites/default/files/publications/Danish_Energy_Authority_2006.pdf

DHI. (n.d.). Offshore Wind – Solutions to Global Challenges – DHI Water Challenges [Press release]. Retrieved January 2021, from https://waterchallenges.dhigroup.com/offshore-wind/

K&L Gates, SNC Lavalin, & Atkins. (2018). Offshore Wind Handbook. https://www.snclavalin.com/~/media/Files/S/SNC-Lavalin/download-centre/en/brochure/offshore-wind-brochure-en.pdf.

Sustainable Development Solutions Network (2020). Mapping the Renewable Energy Sector to the Sustainable Development Goals

United Nations. (2018). Energy - United Nations Sustainable Development. United Nations Sustainable Development. https://www.un.org/sustainabledevelopment/energy/

United Nations. (2018). Oceans - United Nations Sustainable Development. United Nations Sustainable Development; United Nations. https://www.un.org/sustainabledevelopment/oceans/