OREAC
OCEAN RENEWABLE ENERGY
ACTION COALITION

THE POWER OF OUR OCEAN

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OREAC Members

Supporting Organisations

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Foreword

Recent global events have heralded a period of reflection and refocus – a new way of thinking. We have seen people across the world rise to new challenges and demonstrate a "can-do" attitude that inspires hope. It's this high level of passion and ambition that we need to maintain if we are to truly make an impact in the fight against climate change and ensure the security and stability of our society and our global economy.

Our planet's vast ocean provide both possibilities and natural tools we so urgently need to achieve these climate goals. It's our firm belief that ocean-based climate action, through the accelerated deployment of sustainable technologies such as offshore wind, floating, tidal, and wave power holds an essential key to a successful journey to net-zero.

The Ocean Renewable Energy Action Coalition (OREAC) was formed in response to the Call for Ocean-Based Climate Action made by the High Level Panel for a Sustainable Ocean Economy (Ocean Panel).

Bringing together a wealth of knowledge, skills and technical expertise, OREAC provides this report to support the sustainable scale up of ocean-based renewable energy.

This report highlights the essential building blocks to develop government and industry partnerships by using the successful examples and lessons found in existing markets, to accelerate sustainable deployment of ocean-based energy around the world.

Offshore wind is a prime example. Through impressive cost reductions, driven by continuous

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deployment, the industry has grown by over 30% per annum in the past decade, outcompeting many fossil fuel alternatives. In the UK alone, offshore wind already provides around 10% of electricity demand and, with costs continuing to fall, the potential for future deployment at pace remains strong. In addition to providing clean low-cost energy and environmental benefits, the offshore wind industry is having a transformative economic effect through job creation, investments in supply chains and export opportunities.

It's our aim to see these benefits maximised globally in a sustainable way. But it is important to remember that ocean-based renewable energy cannot reach its full potential without the committed and wide-ranging support of governments. Through partnerships and effective planning, OREAC is ready to work with policymakers worldwide to bring ocean-based renewable energy to life and tackle the most pressing issue of our generation, tackling climate change through sustainable economic development.

Source: Ørsted

Contents

Our vision is to have 1.4TW of offshore wind renewable energy capacity in 2050.

Offshore wind delivers at **scale**.

A good government strategy creates an environment where the industry can thrive and create long-term jobs while reducing cost of energy.

Putting the **community and local voices** at the centre of our engagement.

Co-existence with other marine users is vital to the development of the oceans.

Emerging ocean-based renewable energy technologies such as wave and tidal will play a part in the developing the ocean economy.

If our vision is achieved, we could **save over 2.3 billion tonnes of CO_2 per year**

Offshore wind delivers **affordable electricity** prices.

1.4TW of offshore wind could **save 78 trillion litres** of water per year

The industry works to **embed health and safety** as a value in the culture of organisations so that everyone takes responsibility and cares for one another.

If our vision is achieved, offshore wind will supply around **10%** of **the world's electricity**.

Offshore wind boosts **economic growth**.

The offshore wind industry strives to reduce its **environmental footprint**. As well as producing clean energy, the industry is committed to minimising its disturbance of local wildlife habitats.

1. Our vision

To avoid the irreversible impacts of climate change, the world must reduce greenhouse gas (GHG) emissions. The ocean covers nearly three-quarters of the world, and ocean-based renewable energy is a major opportunity to combat climate change and develop a greener, healthier and wealthier world.

Our 1.4TW vision for 2050

Our vision is to have 1.4TW of ocean-based renewable energy generating capacity installed by 2050, achieved with offshore wind. Oceans would then supply around 10% of the world's electricity.[1]

Every region of the world can have a thriving and sustainable ocean-based renewable energy industry. By doing so, countries can replace fossil-fuel generation, and enable widescale electrification of heating, cooling, industry, hydrogen production and transport.

Our vision creates an opportunity to make fundamental changes to energy systems across the world, which are vital if we are to limit climate change and provide economic and environmental benefits for all.

This document focuses on offshore wind as it is a proven mature technology that can make the biggest impact to emissions reduction by 2050.

Our vision is bold and ambitious. In its 2019 World Energy Outlook, the International Energy Agency (IEA) Sustainable Development Scenario has up to 570GW of offshore wind in 2040.[2] If achieved, the world would be on track to reach about 1TW in 2050. The International Renewable Energy Agency (IRENA) also has a 1TW ambition by 2050.

Although offshore wind has the greatest potential for high volumes of ocean-based renewable energy at reasonable cost, there is an important path to commercialisation for other technologies, such as wave and tidal stream energy. These could provide an additional 0.3 TW of installed capacity ocean-based energy by 2050.[3] These emerging technologies can enhance the energy security and independence provided by offshore wind and are described in Chapter 8.

Chapter 8: What other technologies can be used to harness ocean-based renewable energy?

1 Global Energy Transformation: A Roadmap to 2050, 2019, IRENA forecasts annual electricity demand in 2050 of 55,000TWh.
2 This increases if it can be used to provide a low-cost source of hydrogen.
3 This figure comes from An International Vision for Ocean Energy, 2017, Technology Collaboration Programme for Ocean Energy Systems

It is vital that industry and governments work together to deliver the economic and social benefits – only with collective effort will the benefits of this vision be delivered.

Our vision is for global deployment of sustainable ocean-based renewable energy capacity and for all populated continents to develop thriving ocean-based energy industries.

In 2018, The High Level Panel for a Sustainable Ocean Economy (Ocean Panel) undertook an assessment of the climate change mitigation potential of a range of ocean-based activities. It found that ocean-based renewable technologies could reduce annual emissions by as much as 2.5 billion tonnes of CO_2 by 2050. This would be through the generation of 5,400TWh per year, 10% of the global electricity demand. This equates to 1.4 TW of generating capacity if this demand is met only from offshore wind.[4]

According to the Ocean Panel, oceans can contribute up to 21% of the emissions reductions needed to keep temperatures within 1.5°C of pre-industrial levels. Renewable energy could deliver 45% of the ocean's contribution. Without ocean-based renewable energy, the ocean will not reach its full potential to mitigate climate change.

In response to the Ocean Panel, our vision sets out the scale of this potential for ocean-based energy.

4 Assuming an average capacity factor of 45% for offshore wind farms operating in 2050 and using Ocean Panel's upper estimate of CO_2 mitigation.

A roadmap for sustainable growth

Our vision is for global deployment of sustainable ocean-based renewable energy and for all populated continents to develop thriving ocean-based renewable energy industries.

In established offshore wind markets such as in Europe, offshore wind is viewed as central in developing a carbon-neutral energy system. The European Commission estimates that offshore wind could meet 30% of Europe's energy demand by 2050, which would need capacity of up to 300GW.[5] This target has been adopted by WindEurope[6], which is the European trade association for wind energy.

Asian markets are currently being established and we will see significant growth in offshore wind in North America from 2025.

In 2019, The World Bank noted that most offshore wind development had taken place in Organisation for Economic Co-operation and Development (OECD) countries. Growth will continue apace in OECD countries but there is also enormous potential for other countries to benefit by establishing offshore wind markets.[7]

In order to deploy the capacity needed to meet our vision, we recommend a series of five fundamental building blocks:

- **Stable policies**
- **Pipeline visibility**
- **Resourced institutions**
- **A supportive and engaged public, and**
- **A competitive environment.**

We explore these building blocks in more detail in Chapter 3: What is the best way to realise the benefits of offshore wind industry in your country?

A central pillar to the success of further offshore wind growth will be the industry's relationship with other marine users and the protection of sensitive ecosystems. We recognise the importance of continued government efforts to manage marine space and resources carefully.

We explore key aspects of this area in Chapter 4: How do we coexist with other marine uses?

5 A Clean Planet for All: A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, 2018, European Commission
6 Our energy, our future: How offshore wind will help Europe go carbon-neutral, 2019 WindEurope
7 Going Global: Expanding Offshore Wind to Emerging Markets, October 2019, World Bank. http://documents.worldbank.org/curated/en/716891572457609829/pdf/Going-Global-Expanding-Offshore-Wind-To-Emerging-Markets.pdf

In realising our vision, we will help to meet the United Nation's (UN's) sustainable development goals.

7 AFFORDABLE AND CLEAN ENERGY

We will deliver low-cost power to consumers

See **Chapter 2: What can offshore wind do for your country?**

8 DECENT WORK AND ECONOMIC GROWTH

We will create well-paid, long-term and safe jobs

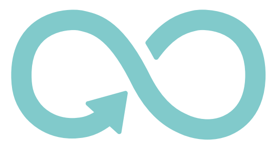
See **Chapter 5: How can you create jobs?**

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

We will invest in new coastal infrastructure for the 21st century

See **Chapter 3: What is the best way to realise the benefits of offshore wind industry in your country?**

12 RESPONSIBLE CONSUMPTION AND PRODUCTION



We will minimise the impact of our activities on the environment

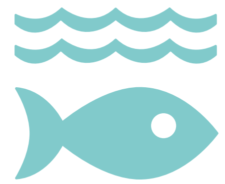
See **Chapter 6: How do we minimise the impact on the environment?**

13 CLIMATE ACTION

Our investments in ocean renewables will be a vital element in nations' efforts to mitigate climate change

See **Chapter 2: What can offshore wind do for your country?**

14 LIFE BELOW WATER



We will appropriately manage our impact on marine wildlife

See **Chapter 7: How do we minimise the impact on the environment?**

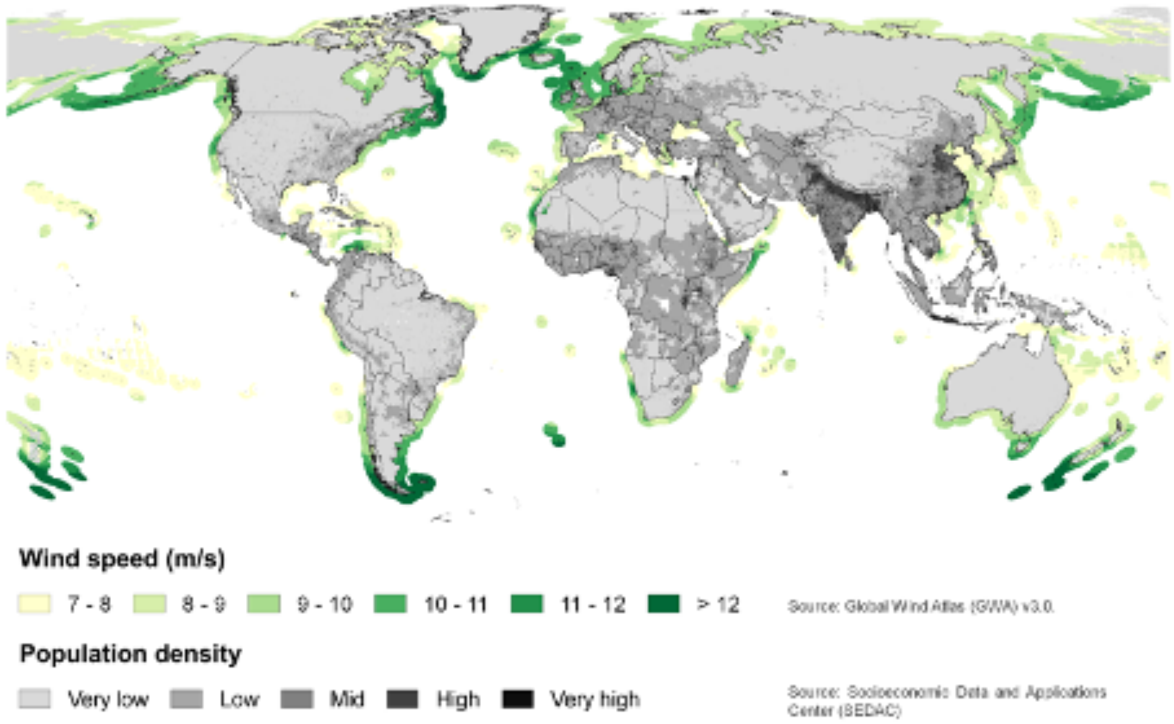


Figure 1 Map of average wind speed at 100m above sea level within 200km of shore and population density.

Where can this 1.4TW offshore wind capacity be built?

Offshore wind projects need good wind resource. Ideally, they will be near areas of high coastal population to allow a more direct route for the delivery of electricity to users, reducing transmission costs and the construction of onshore power lines.

Offshore wind farms have mostly been located close to shore (10 – 60km), but more are being deployed further from shore (60 – 200km) to access areas with higher wind speeds.

Most offshore wind projects constructed so far have average wind speeds greater than 9m/s at 100m height above sea level. We expect that this threshold of economic viability will reduce to 7m/s as the industry develops offshore turbines for low-wind sites, much as it has done for onshore wind. Figure 1 shows that there are significant coastal areas with average wind speeds greater than 7m/s, globally.

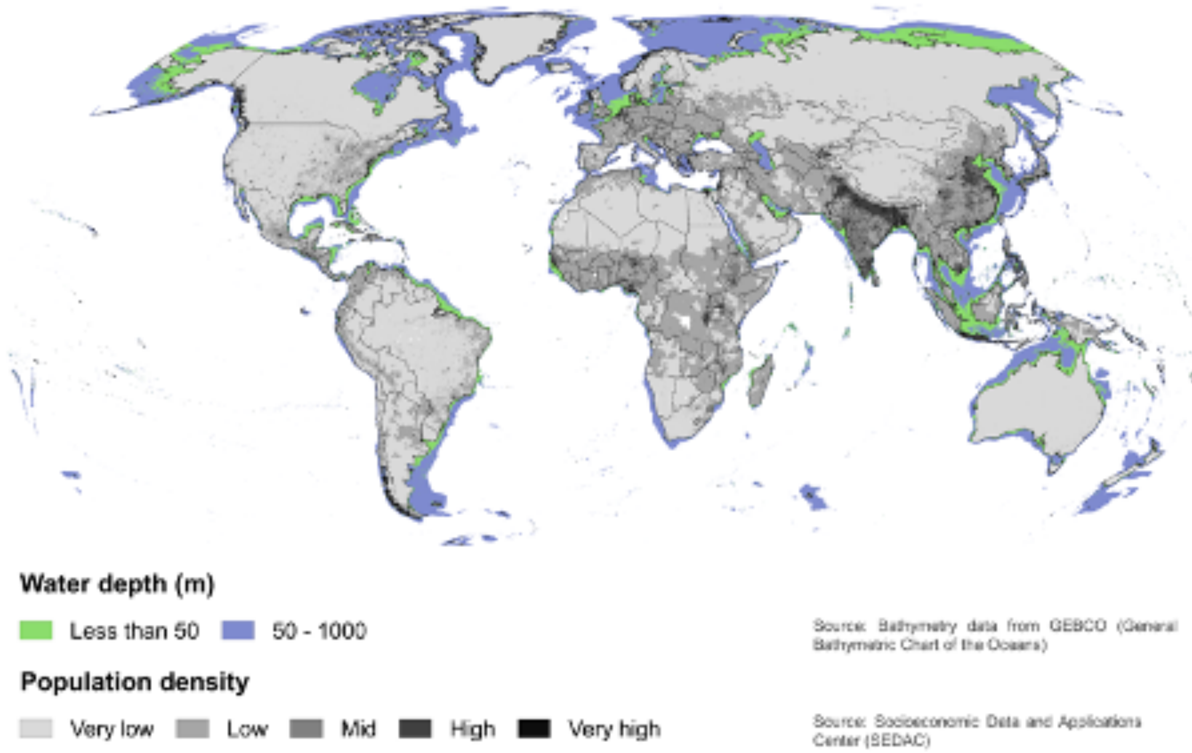


Figure 2 Map of water depth with population density.

Floating wind farms will be key in realising our vision

The vast majority of offshore wind farms installed to date have foundations fixed to the sea bed in waters less than 50m deep. As fixed foundations are technically proven and commercially advanced, most countries will develop markets in shallow waters first. Through continuous deployment, we anticipate floating projects to be cost competitive by 2030 and about 15% of all offshore wind generating capacity installed by 2050 to use floating foundations. Initially these will be installed in waters up to 250m deep, but projects could be installed in waters up to 1,000m deep. Figure 2 shows global water depths to 1000m.

The offshore wind story

Offshore wind will make a substantial contribution to the global energy transition in 2050 because it can deliver at scale and has already shown it generates affordable energy.

In 2005, there was less than 1GW of offshore wind operating globally. This was mostly built close to shore in Europe with projects generally less than 100MW in size. In 2019 alone, 8GW of new capacity was added to bring the global total to over 30GW.

According to the World Bank, in 2015 an offshore wind project in Europe had a cost of energy of $150-200/MWh. In 2019, new projects were successful in auctions with a price equivalent to a cost of energy of below $60/MWh. Cost reduction has been achieved through continuous deployment, enabling innovation, learning and investment in equipment and manufacturing, all driven by competition.

An offshore wind project has many identical turbines mounted on almost identical foundations. The industry has become highly efficient at manufacturing and installing large quantities of turbines, which reduces cost and risk. At a time when many large infrastructure projects frequently run over budget and time, offshore wind routinely delivers to plan.[8]

The cost reduction journey is not over. As the industry expands into new areas, new approaches, such as floating foundations, are being deployed. A truly global industry will support new turbine designs for low wind sites or to withstand tropical storms. Newer, larger designs will be developed, reducing overall capital costs and requiring less maintenance during long operating lives.

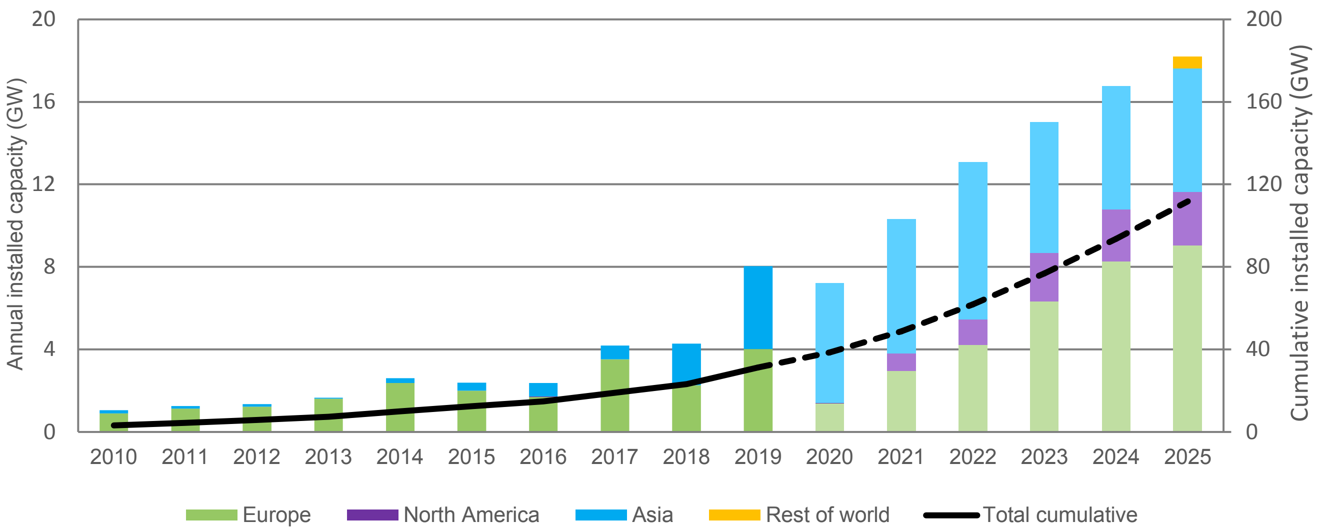


Figure 3 Offshore wind installation from 2010 to 2030. Source: GWEC

8 Spotlight on power and utility megaprojects — formulas for success: Part 1: Financing and delivery, Ernst & Young https://www.ey.com/Publication/vwLUAssets/ey-spotlight-on-power-and-utility-megaprojects/$File/ey-spotlight-on-power-and-utility-megaprojects.pdf

Offshore wind has grown in countries that first realised the many benefits it brings. The early offshore wind farms were built in Denmark, taking advantage of the space and high wind resource offshore. Offshore wind has become one of its most important industrial sectors.

Many offshore wind pioneers such as Germany and the UK have historically relied heavily on fossil fuel electricity generation. The technology provides a significant opportunity to decarbonise their electricity production as coal power stations are phased out. Furthermore, in Germany, commitments have been made to phase out nuclear production and offshore wind has been an obvious choice to replace capacity with significant environmental benefits. It can also help to meet increased electricity demand, as demonstrated in China.

In countries with significant offshore wind capacity already, governments have seen offshore wind as a means of meeting policy objectives and have seen significant economic benefits from kick-starting a new industry.

Strong political support has given the supply chain the confidence to invest. Offshore wind is now a thriving and competitive industry, continually offering new approaches to reduce the cost of energy.

We explore this is in more detail in Chapter 3: What is the best way to realise the benefits of offshore wind industry in your country?

Source: Formosa 1 Offshore Wind Farm, Taiwan; Courtesy of JERA Co., Inc, Partner of Formosa

2. What can offshore wind do for your country?

Offshore wind can be built at an industrial scale. It has very low carbon emissions, produces few atmospheric pollutants and has a very low demand for water. The cost of offshore wind continues to fall year-on-year and will develop local economies.

Once commercialised, other ocean-based renewable energy technologies can be equally beneficial. They also rely on free and predictable energy resources, replacing fossil fuel plants and stimulating local economies.

Offshore wind delivers affordable electricity prices

The cost reduction journey can be seen in many markets where offshore wind has delivered prices below forecasted wholesale market prices.

As seen in Europe, offshore wind prices fall when there is a big enough national or regional market to stimulate local investment and sustain learning and competition.

Analysis has shown that new offshore wind capacity will become cheaper than new fossil fuel capacity early in the 2020s (see Figure 4).

Offshore wind delivers clean power to millions of homes

Over the past 10 years, the average offshore wind turbine capacity has grown from 2MW of capacity to over 12MW, and 15MW turbines are not far away. Turbine rotor diameters have grown from 60m to over 200m. Wind farm sizes have changed from the tens of MW in size (for example North Hoyle Wind Farm, 60MW in the UK's Irish Sea in 2003) to multiple gigawatt size. The 1,200MW Hornsea Project One in the North Sea was completed in 2020 and will power more than a million homes.[9]

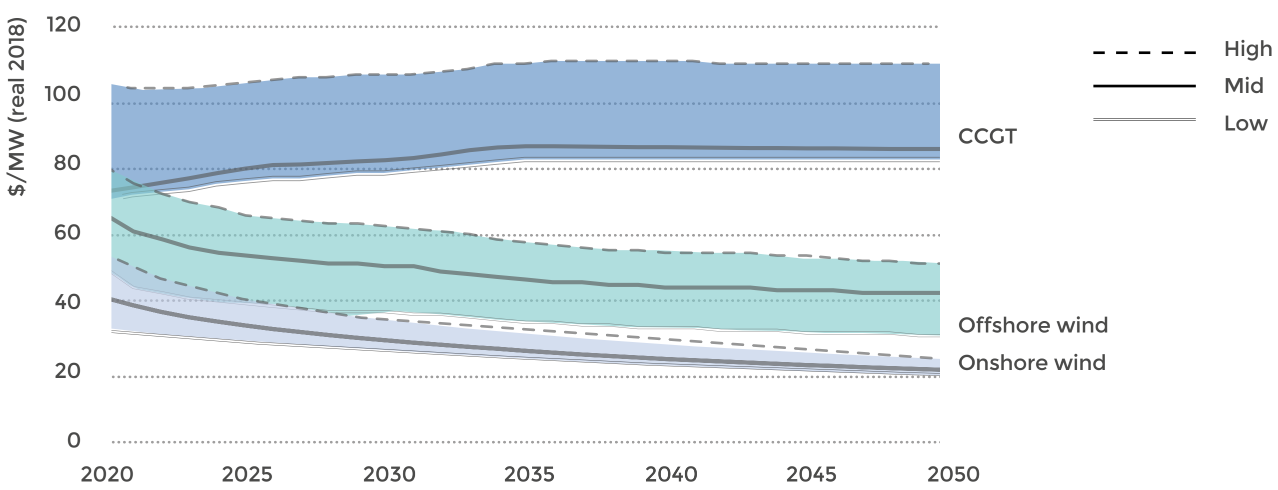


Figure 4 Future UK levelised cost of energy of wind and fossil fuel power generation. Source: BloombergNEF (2020)

9 https://hornseaprojectone.co.uk/about-the-project#0

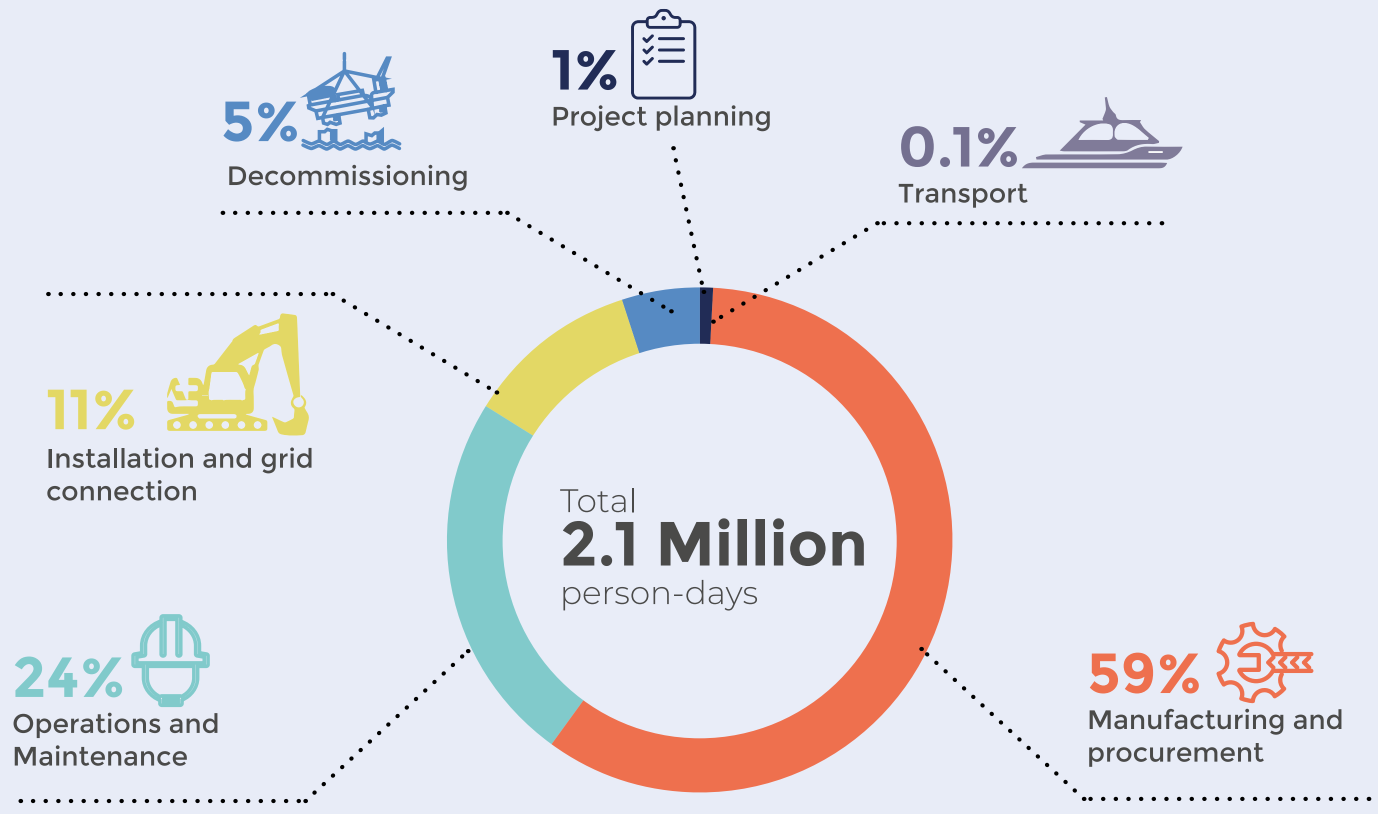


Figure 5 Job creation for an offshore wind farm. Source: IRENA 2018 [14]

Offshore wind reduces carbon emissions

According to a report commissioned by the Ocean Panel, ocean-based renewable energy could deliver around 10% of the global CO_2 emissions reductions required by 2050 to sustain a 1.5-degree pathway.

Fossil fuels release on average 460 tonnes of CO_2 per GWh of electricity generated.[10] If our vision of 1.4TW of offshore wind in 2050 is realised, it will generate 5,400TWh annually, saving over 2.5 billion tonnes of CO_2 emissions per year. That is equivalent of taking more than half (800 million) of the world's cars off the road.

Life-cycle analysis by Siemens Gamesa Renewable Energy found that the energy payback time for their wind power plant is less than 7.4 months. That is the length of time the wind power plant has to operate in order to produce as much energy as it will consume during its entire lifetime.

Offshore wind boosts economic growth

Offshore wind creates demand for a wide range of components and services, leading to new jobs and local economic development. It offers a clean growth pathway, transitioning the workforce and industrial sectors to meet future needs, while providing a sustainable means of meeting growing energy demand.

IRENA estimated that a 500MW offshore wind project creates directly 2.1 million person days of work or about 10,000 person years over its life.[11]

10 https://hornseaprojectone.co.uk/about-the-project#0
11 Ocean Panel report assumption

Offshore wind presents an opportunity to revitalise coastal towns, cities and communities, where new investments can regenerate areas that have previously faced economic decline. The industry has also worked to ensure a just transition of workers from other sectors in decline, such as fishing.

Chapter 5: How can you best create jobs? explores how to maximise job creation in offshore wind.

Offshore wind delivers energy security

Offshore wind can fill the gap left by retiring fossil fuel capacity and meet demand from the electrification of transport and heating. It can reduce reliance on imported energy, which can be subject to significant price fluctuations.

According to the IEA, "Offshore wind's high capacity factors and lower variability make its system value comparable to baseload technologies, placing it in a category of its own – a variable baseload technology".[12]

For countries that have grids built to transmit power from traditional fossil fuel generation to population centres, offshore wind may drive changes to enable these systems to evolve towards carbon neutrality. This whole system transition could include grid reinforcement, new mechanisms and technologies to balance electricity supply and demand, and much closer links between electricity, transport and heat systems. As an example, offshore wind is already being linked with the development of the hydrogen economy and other forms of 'power to X'.[13] In this way, it can support the decarbonisation of all energy production, not just electricity.

The approach taken by a country to develop its generation mix and grid system should reflect its unique characteristics of resources and demand.

Offshore wind reduces pollution

Compared to generating from fossil fuels, offshore wind helps cut significant amounts of atmospheric pollutants.

Sulphur dioxide (SO_2) and nitrogen oxides (NOx) are air pollutants that create smog and trigger asthma attacks and other respiratory issues.[14] Fossil fuels release on average 1.1 tonne of SO_2 and 0.7 tonnes of NOx per GWh of electricity generated.[15] If our vision is achieved, offshore wind will save 5.8 million tonnes of SO_2 and 3.7 million tonnes of NOx a year, by 2050.

In 2018, The American Wind Energy Association estimated the reductions in air pollution from the 96 GW of onshore wind generated $9.4 billion in public health savings, just in that year.[16] The impact of 1.4TW offshore wind in 2050 would be about 20 times higher.

Offshore wind energy saves water

Thermal power plants require water to produce electricity and cool power generating equipment, with fossil fuel generation potentially consuming on average 15 million litres of water per GWh.[17] Wind farms can save a significant amount of water, with 1.4TW of offshore wind potentially saving 78 trillion liters of water per year.

12 Global Offshore Wind Outlook, October 2019, IEA
13 Power-to-X is electricity conversion, energy storage or reconversion technology that uses surplus electric power, typically during periods where fluctuating renewable energy generation exceeds load.
14 American Wind Energy Association data:
15 Based on data from the US Energy Information Agency. The amount saved pollutant will depend on which fossil fuels are displaced.
16 https://www.awea.org/wind-101/benefits-of-wind/environmental-benefits
17 US Energy Information Agency

Source: Ørsted

Working to support grid stability

As more variable renewable energy such as wind and solar is installed, electricity grid operators will continue to manage supply and demand, where grid flexibility and other technical solutions are needed to minimise balancing costs and deliver system stability.

Offshore wind projects are being connected to energy storage solutions to help support system for stability, for example, Equinor's 1.34MWh Batwind battery stores excess electricity generated from the world's first commercial floating windfarm, the 30MW Hywind Scotland.[18]

The offshore wind industry will continue to work with electricity transmission operators and regulators to develop solutions that meet countries' needs. In time, further solutions will consider transport and heat, as well as electricity.

18 https://masdar.ae/en/masdar-clean-energy/projects/batwind

UK offshore wind revolution

The UK is currently the largest offshore wind market in the world. The UK Government set clear electricity decarbonisation target ambitions, imposed an additional carbon tax and mandated that all coal powered generation cease by the mid-2020s. This mix of targets and market-based policy mechanisms has transformed the UK energy mix, with coal dropping from the dominant source of generation to almost nothing in less than seven years.

The UK offshore wind industry has been developing since 2000. What was once a small, niche industry now generates 10% of UK generation with around 10GW of installed capacity.

In 2018, the UK Government developed a new Industrial Strategy and worked with industry to agree a Sector Deal for offshore wind. The Government pledged to enable a total installed offshore wind capacity of 30GW by 2030. This will mean 30% of generation will be met by offshore wind by 2030. The Government and industry also agreed to work closely together to increase the lifetime local content in UK offshore wind farms from 50% to 60%.

In 2020, the installed capacity target was increased to 40GW by 2030. If delivered, in that year, it would save 70 million tonnes of CO_2, 160,000 tonnes of SO_2, 100,000 tonnes of NOx and 2.2 trillion litres of water.

The UK has seen significant changes to its energy system over the past years. In 2019 UK carbon emissions fell for the seventh consecutive year in a row, after a record year of renewable energy generation.[19] In 2017, there was a total of 3 coal free days in the UK, and in 2019 this increased to 83 days,[20] and by May 2020 was the UK's first coal-free month since the industrial revolution. [21]

With the introduction of competitive auctions in 2015, the UK has seen the cost of offshore wind fall by over 60% and is now delivering offshore wind farms at below the wholesale market electricity price.[22]

Source: Ørtsed

19 UK Government statistics https://www.gov.uk/government/statistics/provisional-uk-greenhouse-gas-emissions-national-statistics-2018
20 Analysis by Carbon Brief, 2019: https://www.carbonbrief.org/wp-content/uploads/2020/01/83-days-in-2019.png
21 Britain's Electricity Explained: May 2020, National Grid https://www.nationalgrideso.com/document/168706/download
22 Contracts for Difference Allocation Round 3 results, 2019. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/838914/cfd-ar3-results-corrected-111019.pdf

3. What is the best way to realise the benefits of an offshore wind industry in your country?

Offshore wind will flourish in an environment where policies and regulation are aligned to deliver clear objectives. This reduces risk and encourages investment. With these building blocks, the offshore wind industry can maximise the many benefits to countries. Effective stakeholder engagement is crucial throughout the process.

Stable policies

Industry welcomes strong government leadership to help it deliver rapid benefits. It may take eight years or more from the start of development to operation of the wind farm and the policy framework needs to be in place early.

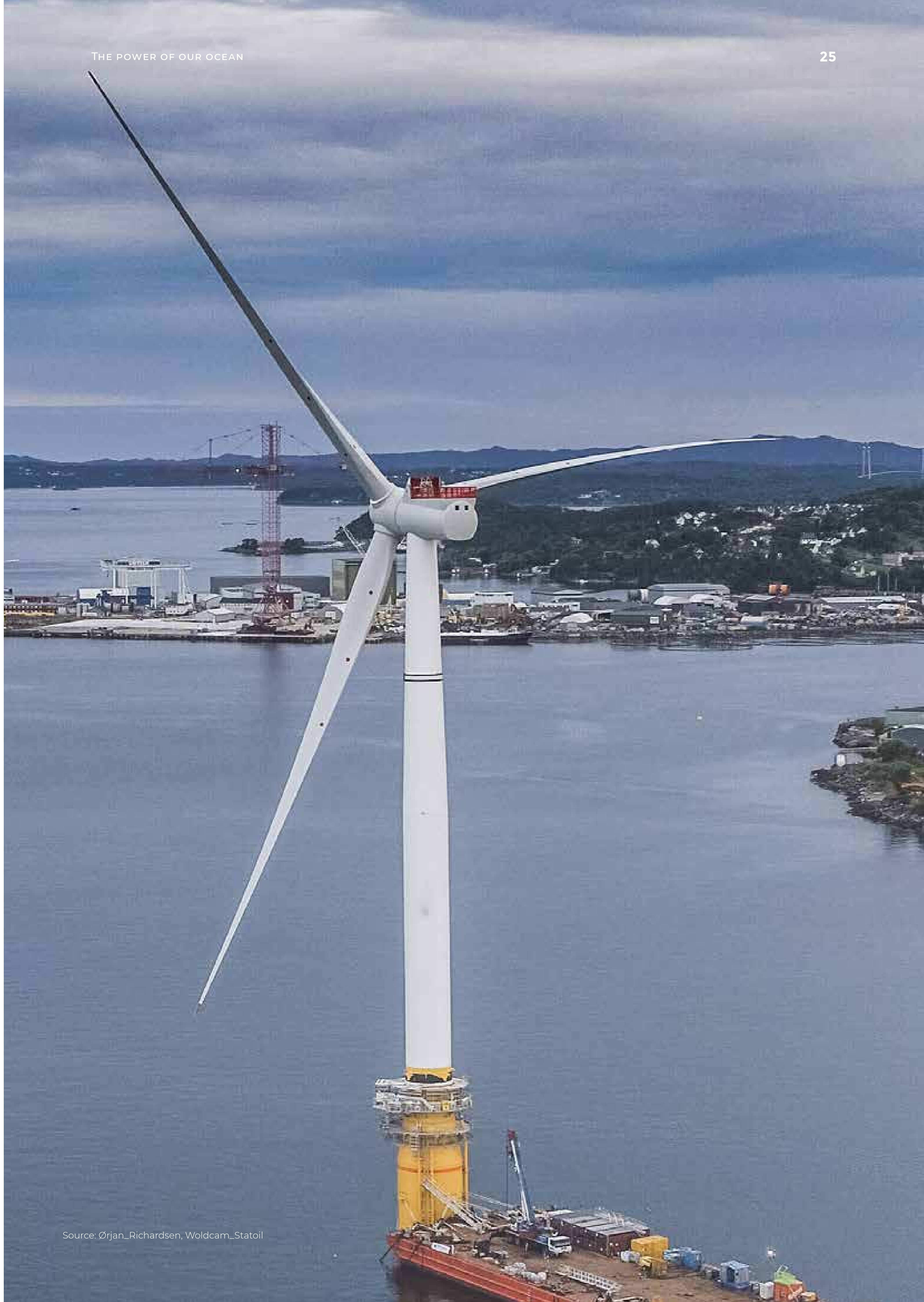
Governments may have many reasons why they wish to develop offshore wind, such as slowing climate change, increasing energy security, and providing local economic development. Industry values clear policies from governments as these give the confidence to invest and commit to markets. The benefits of offshore wind are greatest where this comes from a long-term vision from senior figures in government that sets ambitious but achievable goals for offshore wind.

With a strong policy intent, enabling frameworks can be put in place, providing:

1. Pipeline visibility: Sufficient, attractive lease areas for development
2. A clear, efficient and open permitting process
3. A power purchase regime that de-risks developers' exposure to long-term energy price fluctuation, to create more competitive projects and lower energy prices.[23]

Countries will make different conclusions about how to deliver these building blocks. Stakeholder engagement can shape the direction of the industry and build a consensus. Furthermore, stable and bankable legal frameworks which consider adequate arbitration, change of law and force majeure provisions provide confidence for investors.

23 Offshore wind is capital intensive so investors value greater certainty of future revenue



Source: Ørjan_Richardsen, Woldcam_Statoil

1 Pipeline visibility: Sufficient, attractive lease areas for development

With enough space to build wind farms where there is a low cost of energy, countries can achieve their ambitions with competition between sites and developers.

The industry will welcome a leasing process that:

- Offers areas with an inherent low cost of energy.
- Has clear guidelines on what is expected in terms of limiting impact on the environment and interaction with other users of the sea so that developers can judge what is likely to be given planning permission, and
- Makes sites available in a timely manner.

Leasing processes have been designed to raise government funds in some countries, but these also make projects more expensive for developers and risks projects not being built or increasing the costs for consumers.

Source: Ørsted

The power of our ocean

Two approaches to leasing and power purchase

Centralised, single-stage process:
The government identifies specific wind farm sites and does early development work in order to de-risk the sites for developers and provides enough information for them to estimate the value of each site. Typically, developers then bid a price they would be willing to accept for the energy produced from each site, with the lowest price bidder winning rights to develop the site. Denmark, Germany and Netherlands have used this approach. Competition is between several developers bidding to secure a site at a given power price.

***Denmark:** Leasing for offshore wind sites is managed by The Danish Energy Agency (DEA). The DEA is used as a 'one-stop-shop' for all required licences and permitting activities. The DEA announces a site-specific tender for a set project capacity (MW), having completed preliminary environmental investigations through a spatial planning committee and surveys managed by the transmission operator (Energinet). A new energy agreement passed by the Danish parliament in June 2018 supported building an at least an additional 2 400 MW of offshore wind capacity by 2030. This minimum capacity is likely to be awarded through three future tenders.*

Decentralised two-stage process:
Developers secure a lease through one competitive process then bid into a price support auction at a later date. UK, US and the Taiwan region are examples of this approach. Competition is therefore between developers to secure each site, then, later, between sites to secure price support. A healthy supply of sites ensures there is good competition in the price support auction.

***The Taiwan region:** In 2015, the local government designated 36 zones of potential (ZoP) and invited developers to register interest in particular zones. Overlap in developers' choices were resolved through discussions. Developers need an approved environmental impact assessment (EIA) and an Establishment Permit from the Ministry of Economic Affairs (MOEA) to secure the lease. With the Establishment Permit, the developer applies to the Bureau of Energy (BOE) for recognition of project as a renewable energy facility. Within six months of obtaining the Establishment Permit and the BOE recognition, the project developer is required to sign a power purchase agreement (PPA) with the utility Taipower. With or without the Establishment Permit, the developer applies for a Construction Permit from the Bureau of Energy, but it is only granted once the Establishment Permit is issued. The Construction Permit is valid for five years and can be renewed.*

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2 Streamlined permitting process

A clear permitting process makes it more likely that government and other stakeholder concerns about the impact of a development are addressed at an early stage. It ensures that projects are built in a way that best meet the needs of all stakeholders. Everybody gains by knowing what needs to be achieved and by when.

Developers may spend more than US$100 million before a project has all the permits required to build the wind farm. Even in a centralised leasing approach, where governments may undertake some of the permitting activity before the auction, developers often need additional permits for the specific design of the wind farm.

Governments can best deliver their energy strategy if developers have confidence in when their offshore wind projects will get built. They can achieve this with a clear and streamlined process that is easy to understand and follow, adheres to clear timelines on decision making and gives clear requirements for developers to meet.

CASE STUDIES

Effective engagement to address cumulative impacts

US wind farms will mostly be built in federal waters under the auspices of the Bureau of Ocean Energy Management (BOEM). BOEM is responsible for both leasing and permitting, which reduces risks for developers.

BOEM undertook extensive stakeholder engagement in identifying its lease areas. As a result, these areas are located away from important fishing areas, for example. BOEM has also made a significant effort to learn from the approaches in Europe, and in particular in identifying the cumulative impacts from several wind farms built in the same area. This gives considerable confidence to developers of sites leased by BOEM that they will receive the necessary permits from BOEM to build the wind farm.

A one-stop permitting shop

Offshore wind farms are defined as nationally significant infrastructure projects within England and Wales. This means that all the permitting of offshore and onshore infrastructure of the wind farm is considered together at a national level. The process is managed by the Planning Inspectorate (PINS), which is part of central government. PINS commits to completing the process within 18 months of receiving all required information. At the end of the period, PINS makes a recommendation to the Secretary of State, who has three months to decide. Generally, PINS' recommendations are accepted.

The system has the advantage for developers in that they deal with a single organisation and they have confidence that a timely decision is made, which reduces project risk.

Netherlands joined up government

The Netherlands published a roadmap in which 11.5GW of offshore wind will be installed by 2030. This target has been aligned with a series of auctions and offshore grid development.

The Netherlands runs a single-stage leasing and price support system, where developers all bid for the same sites. If a subsidy is required for the construction of the offshore wind farm, the subsidy tender coincides with the permit tender. In this instance, the developer must meet certain requirements and bids will be evaluated on price per MWh. The winning developer secures a contract for difference subsidy for 15 years and a permit to develop and operate an offshore wind project for a 30-year period.

Sites are consented before the auctions, which lowers project risk. Auctions have been very competitive and have led to low prices. In 2019, the Netherlands first subsidy free auction was held.

3 A regime that de-risks developers' exposure to long-term energy price fluctuation

In a new market, the offshore wind industry is likely to need price support until supply chain investments are made and industry learning is consolidated. Offshore wind has high capital costs and low operational costs. It therefore needs significant upfront investment and some form of assurance of revenue in order for the capital costs to be recovered. Governments can play a valuable role in reducing market risks.

The cost of capital depends on the risks perceived by the lender. It is common to pass on financing costs to consumers, however lower fuel bills can be realised, if governments lower investment risks.

Our bold vision for offshore wind reflects the spectacular progress made in reducing costs. In mature markets, industry is on the brink of generating electricity with no net subsidy. Even in mature markets, governments can play an important role in reducing the market risk of developers. Power output over a long period can be forecast with some accuracy. Shorter term variations mean fluctuations in revenue, which means more risk to investors. Support mechanisms that stabilise revenue per MWh can lead to lower prices overall because of the reduction in risk. Developers may see price stability as worthwhile trade-off for receiving lower prices for their electricity.

Each country will choose a mechanism for reducing market risk that works best for its specific market. In an open electricity market, a government will not typically buy power directly and will often adopt a mechanism by which generators are reimbursed when the market price falls below an agreed figure. Contracts for difference are becoming popular, in which the opposite is also the case - the generator pays the government if the market price goes above an agreed 'strike price'.

In less open markets or where the electricity industry is state-owned, it is more common for developers to be paid a fixed price through a power purchase agreement (PPA).

Market prices may also be topped up through tax credits. Guarantees of origin (GO) for renewable energy may also be a mechanism to enable offshore wind to achieve a differential price.

A coherent industrial strategy

Offshore wind can be an important part of a county's industrial strategy. The offshore wind industry can help deliver the strategy though partnerships with country government.

A government's industrial strategy in offshore wind is likely to seek to strike a balance between cost to the consumer and other policy objectives, such as job creation and supply chain development. Industry and government can work together to find the optimal ways work collectively to achieve these objectives.

There can be widespread benefits in helping companies to work together, for example, in forming local industry clusters and undertaking research and development to accelerate cost reduction and collaborate on health and safety.

Furthermore, offshore wind benefits are maximised alongside investments in new port infrastructure for manufacturing or to support project construction. By working together, industry and government can agree what is needed and how it can be funded. In most cases, the infrastructure will be used by different companies, different projects and different industries over many years.

Government support to share and de-risk industry investments means projects are delivered efficiently with more local jobs

Why the cost of finance is important?

Financing costs are a large part of the cost of energy of an offshore wind farm. If the cost of capital is 6%, finance makes up about a 33% of the cost of energy. Increasing the cost of capital by 2% to 8% increases the cost of energy by 15%.[23]

The offshore wind industry has shown that it delivers on time, on budget and can provide attractive returns for investors. Governments can play a leading role also by creating an attractive environment for investment.

Governments can offer stable and attractive policy framework with good visibility of the size of the industry over at least ten years. By providing a competitive and stable mechanism to give some certainty over future revenue, governments can give investors acceptable returns, while ensuring enough competition to deliver offshore wind at the lowest sustainable cost to the country.

A stable economic climate with currency stability or mechanisms to reduce currency risk will also create a better environment for investors.

23 Assumes a 1GW wind farm with a CAPEX of €2 million, an OPEX of €75 thousand per year and a life time of 25 years

A landmark deal between the UK government and industry

In most markets, governments have policy objectives for offshore wind and there are regular discussions with industry on achieving these aims.

The UK Government launched an industrial strategy in 2017 with the aim of agreeing a series of 'Sector Deals' with industry. It chose offshore wind as one of the sectors.

In 2019, the offshore wind Sector Deal was agreed. The Government committed to enable a market in which 30GW of installed capacity could be achieved by 2030 by committing to regular contract for difference auctions. Industry agreed to work together to invest and support the local supply chain and convened the Offshore Wind Growth Partnership to enhance the competitiveness of UK companies in the sector.

Strategic investments in infrastructure

Ports

Offshore wind needs ports to manufacture and assemble large components and as bases for construction and operation. Good infrastructure lowers project costs and risks.

Each country will have different requirements for infrastructure investment, reflecting local factors and the balance between technical and commercial considerations. The industry will evolve new ways of working in new markets.

In Europe, most developments have been in the North Sea and the relatively short distances mean that in many cases components can be loaded out from factories direct to installation vessels. In other markets, this may not be the case and the demands placed on ports will be different.

Source: Siemens Gamesa

There are three main types of offshore wind port, these are manufacturing, construction, and operations.

A manufacturing port hosts production facilities for components that cannot be easily moved by road. This includes assembled turbine nacelles, turbine blades, turbine towers, foundations, offshore substations and subsea cables. The production facilities do not need to be quayside, but they do need unrestricted access to the quay and significant storage areas. A production facility is a long-term investment and suppliers would look for a lease for 10 years or more.

A construction port is where components are preassembled and stored ahead of collection by the installation vessel. They are important in ensuring an efficient construction schedule.

A construction port is often used for two years for the construction of a commercial-scale project. An operations port is the base from which the wind farm is operated, maintained and serviced. The specifications are less demanding, being dependent on the type of vessels being used to maintain and service the wind farm. To minimise logistics costs, the operations port is often the closest port to the wind farm.

In emerging markets, port owners may have little experience of the wind industry and attracting offshore wind tenants may involve a shift in a port's business model. Likewise, potential offshore wind tenants may not fully understand how ports operate in different countries. Governments can play a valuable role in facilitating discussions and enabling investment.

Source: GRI Renewable Industries

CASE STUDIES

A strategic investment driven by clear government commitment

In March 2014 Siemens Gamesa committed to a £310m investment into the UK, creating both a blade manufacturing facility and a world-leading project execution site, partnering with the port owner and operator Associated British Ports.

Green Port Hull was established after an economic study commissioned by Hull City Council identified that ports around the Humber had an opportunity to be a gateway for the UK due to its good location and capacity for growth. Siemens Gamesa's decision to build manufacturing facility in the UK was initially driven by clear commitment from the UK Government to rapidly increase the deployment of offshore wind to meet its 2020 renewable energy targets.

After examining over 50 potential European locations, Hull was chosen because of the unrestricted river access, potential for creation of significant quayside, and a supportive environment for redeployment of existing facilities which reduced the capital investment required.

Growing with the Danish wind industry

The port of Esbjerg has a strong track record in Danish oil and gas and originally served the onshore wind industry through export of turbines to different markets.

In the early 2000s the European offshore wind market began to develop, and Esbjerg contributed to the development of Denmark's first large scale offshore wind farm, Horns Rev I, which was constructed in 2002. The port recognised the potential of the offshore wind industry and devised business cases to leverage investment towards the development of flexible port areas for turbine supply and wind farm construction.

In 2000 the Port of Esbjerg shifted from state ownership to a self-governing public port owned by the Municipality of Esbjerg. The Port of Esbjerg invested approximately $150 million between 2003 and 2014 through municipality loans to develop new areas and facilities to support the offshore wind industry. In 2020, it has plans to build a 60,000m^2 fabrication facility which it intends to lease to clients that fabricate blades, nacelles, towers or foundations.

Industry partnership to serve the Belgian market

The port of Oostende in Belgium traditionally served general cargo, cruises, ferries and fisheries. It first supported the offshore wind industry in 2007 during the construction of the Thornton Bank offshore wind farm.

The Renewable Energy Base Oostende (REBO) was established at the Port of Oostende in 2010. REBO sought to develop port infrastructure and services to support construction and operations & maintenance in offshore wind across a 15 hectare site. REBO invested approximately $18 million, leveraging support from Artes-Group, DEME and PMV to create a new terminal with a reinforced quay, berths for installation vessels, warehouse, and office space. The investment had risk as it was uncertain how the offshore wind industry would evolve. As the port has now facilitated the construction of several offshore wind farms and is home to a cluster of offshore service companies, this investment has proved successful.

Last year the Port of Oostende became 100% owner of REBO. The Port of Oostende will increasingly focus on attracting companies involved in operations and maintenance. It will also start construction on a new heavy weight quay to support wind turbine and oil and gas decommissioning.

Long-term commitment encourages industry investment

China is one of the fastest growing markets for offshore wind in the world. Guangdong's Offshore Development Master Plan has established that at least 66GW will come from the Guangdong region alone towards 2030. This long-term commitment encouraged GE to open the new offshore wind turbine factory at Jieyang's offshore wind cluster and to establish a new operation and development centre in the city of Guangzhou.

The new factory in Jieyang will help to meet Chinese growing demand for offshore wind energy and will serve domestic and regional projects. It will take up 7 hectares and employ 400 workers. GE has been supported by the local government with investment and skills development.

Source: MingYang Smart Energy

Strategic investment to achieve a long-term vision

The Taiwan region has ambitious capacity targets of 5.5 GW by 2025 and a further 10 GW by 2035. These enable long-term planning and provide a platform to attract investment.

Port development is an important part of the long-term strategic planning of infrastructure that supports the manufacturing, construction, transport and operation needs of offshore wind projects. The Taiwan International Ports Corporation (TIPC) is working with local and international industry partners to develop the Port of Taichung, in central Taiwan region, into a hub for offshore wind logistics and assembly.

Dedicated wharves will be used to produce, store, assemble and transport components. From 2020, an estimated 30-40 turbines will be assembled in Taichung each year, while international companies like MHI Vestas and Siemens Gamesa have made investments in local facilities and partnerships in Taichung for the manufacturing of offshore wind blades and nacelles, respectively.

Grid

Offshore wind farms can be built close to population centres, but investment may still be needed to connect the wind farm to the onshore transmission network. This can take many years of planning.

For offshore wind to play a major role in a country's energy mix, electricity must be transmitted to locations of demand. New grid infrastructure is therefore essential to delivering offshore wind, but large coastal demand centres can be supplied without the addition of long onshore grid connections.

Traditionally, grids were developed to transfer dispatchable power from fossil fuel power stations to demand centres. Grids need to be adapted to a system with generation that varies with the weather and is in more remote locations.

There are often long lead times to reinforce the onshore grid. A strategic approach to developing grid infrastructure is helpful when developing an offshore wind industry. This should consider both onshore and offshore grids.

Each country has specific energy needs and infrastructure and technology solutions are likely, in time, to include storage and power to gas. These enable greater flexibility in energy supply.

There are different options for countries to build and operate offshore transmission. Investors value robust regulations covering the responsibilities of the transmission owners. Further consideration is needed to ensure the grid system is developed and designed to maintain continued balance between supply and demand. Investors will need to be comfortable that there is enough demand to absorb the power that is being produced.

Joined up thinking to optimise grid infrastructure

In 2014, the Dutch Government published a roadmap for 3.5 GW offshore wind by 2023 and decided to develop the associated offshore grid in a coordinated way. In close consultation with the national grid operator, TenneT, it was agreed that the wind farms would each be of capacity 700 MW. This enabled the development of a standardised 700 MW offshore transformer platform. The first standardised 700 MW HVAC offshore grid connection was delivered in September 2019.

Given the success of the first offshore wind tenders in achieving low prices, the Government published a second roadmap for an additional 6.1 GW offshore wind by 2030. For this roadmap, different technical solutions to connect the expected windfarms were developed and evaluated. As a result, TenneT is now working with the wind industry to develop a standardised 2GW offshore HVDC platform.

The right locations

Wind resource

The wind resource plays a significant role in any business case for an offshore wind farm, where higher wind speeds yield more energy production.

Most development so far has been at sites with average wind speeds of 9m/s or greater at a height 100m above mean sea level. Over the next 15 years, sites with average wind speeds of 7m/s will become commercially attractive through the development on new turbines and cost reduction across the whole supply chain.

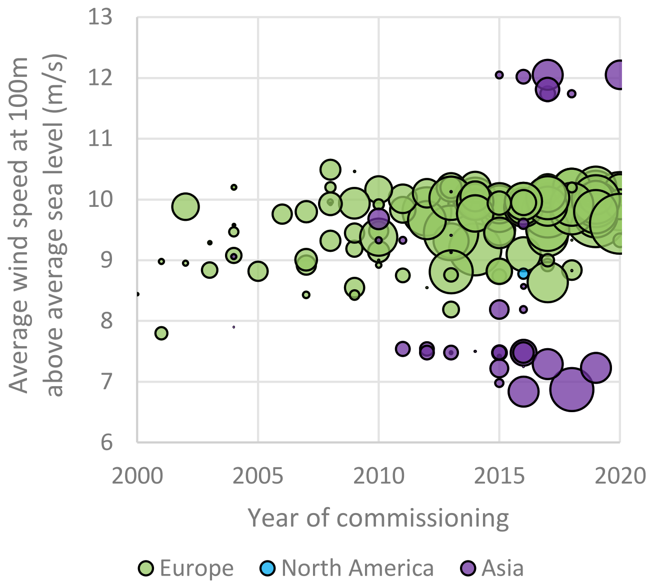


Figure 6 Average wind speeds at 100m above mean sea level for offshore wind farms.

Distance from shore

Developments further from shore are more expensive due to higher logistics and transmission costs but can be economical by accessing higher wind speeds. Rapid cost reductions in floating wind and high voltage direct current (HVDC) technology costs will extend the range. Up to now, most wind farms have been built within 100km but in the UK, construction will begin in 2023 on a series of wind farms that are more than 150km from shore.

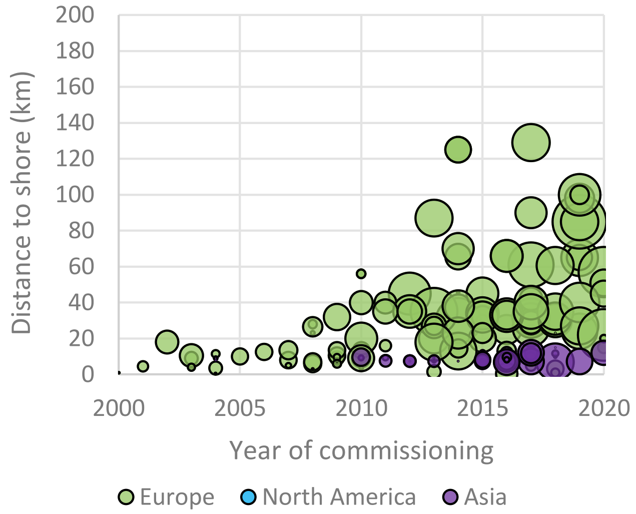


Figure 7 Distance to shore for offshore wind farms.

Water depth

Fixed bottom wind farms are generally limited to water depths less than 50m. The offshore wind industry is now taking its first steps to develop floating wind farms, which can access good wind resource in deeper water. This move opens up up vast new areas of the ocean and they could eventually be built in waters up to 1000m deep. We expect this market to grow rapidly after 2025.

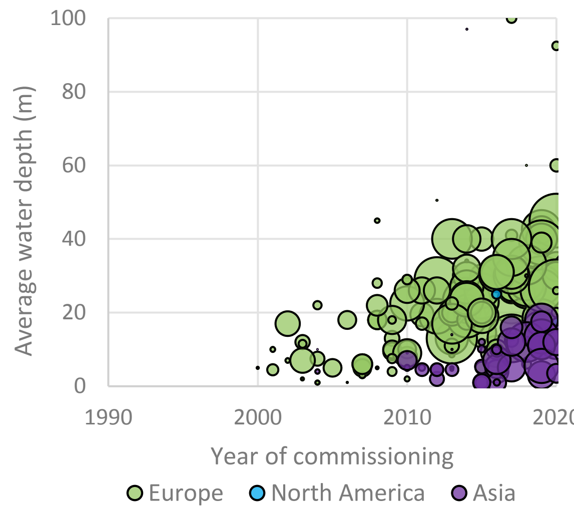


Figure 8 Water depths for offshore wind farms.

Resourced institutions

Governments can best achieve their objectives for offshore wind if they give robust and timely leasing, permitting and PPA decisions.

Institutions involved in environmental management, leasing sites, permitting and providing market support mechanisms need to be sufficiently resourced. These institutions create an environment where industry has confidence to make business decisions and governments can have confidence that policy objectives are being achieved. Furthermore, clear, transparent and timely permit or consent processes will support investment decisions for developers and investors.

It is not just the organisations directly involved in the support of the offshore wind industry that need resources. Offshore wind farms also have implications for military, aviation and environmental protection. All organisations that need to be consulted will benefit from sufficient resources to develop a good understanding of issues, in order to process offshore wind requests.

The gradual growth in the industry in Europe, with demonstration and pathfinder projects, means that many organisations have learnt much about the impact of offshore wind and how to manage risks. As offshore wind globalises, the offshore wind industry is committed to helping to share that learning.

Supportive and engaged local communities

Voices of individuals and organisations affected by offshore wind farms must be heard and it is vital that the industry engages with communities and businesses. Governments can provide a channel for these voices and the industry will proactively engage.

Today's offshore wind farms are large industrial developments and they affect people's lives and environments. It is right that industry informs the public of its plans and the potential impacts – good or bad. We understand that even a well-informed public may still have concerns. A key part of engagement is sharing the benefits of offshore wind on carbon reduction, job creation, and economic development potential.

The offshore wind industry works hard to listen to and inform national and local stakeholders about projects.

The process of stakeholder engagement should start before project development and is best aligned with marine spatial planning.

See Chapter 4: How do we coexist with other marine uses?

Competitive environment

Competition typically drives efficiency and innovation. Long-term, this reduces costs for governments and consumers and enables local suppliers to compete, regionally and globally.

Energy markets around the world range from fully liberalised markets to state-controlled markets. Regardless of the system, we have found that competition can have a significant impact on power prices.

Competition for sites and price support means the best projects get built by the most competitive developers and offer best value. But there is a delicate balance to strike. Too few sites may mean less competition for price support. Too many sites and too much project development is at risk, which will ultimately be reflected in higher power prices.

Source: Ørsted

4. How do we coexist with other marine users?

All coastal nations have important, existing maritime industries. Many are seeking to grow the 'Blue Economy' to help drive job creation. It is vital to establish a sustainable offshore wind industry that delivers maximum positive impact while ensuring the impacts on other marine users and the environment from wind farm development are carefully managed.

A strategic approach

Marine spatial planning (MSP) helps to efficiently accommodate different users of the seas and protect sensitive ecosystems.

In determining offshore wind opportunities, countries can usefully consider what areas are suitable for offshore wind and how to place its benefits in a wider strategic context.

Creating opportunities

Effective MSP is a tool to:

- Identify areas with an inherent low cost of energy
- Reduce sector conflicts and create synergies
- Encourage investment – by providing predictability, transparency and clarity
- Increase cross-border cooperation to develop energy grids, shipping lanes, pipelines, submarine cables and other activities
- Protect the environment, and
- Enable efficient co-location where it makes sense

MSP will help establish how much offshore wind can be built and where. It is a vital input to countries' offshore wind strategies. Without it, a government cannot have confidence its country's offshore wind vision can be realised. It is worth noting that MSP can also be considered regionally, i.e. across offshore wind borders, such as the North Sea or Baltic Sea, where wind farms in different jurisdictions may be close together.

MSP is a tool to support appropriate and sustainable management of the marine environment, by facilitating early identification of environmental impacts caused by users of the sea, and identifying opportunities for more controlled multiple use of space.

The offshore wind industry's commitment to the environment is presented in Chapter 7: How do we minimise the impact on the environment?

- STEP 1 Establishing Authority
- STEP 2 Obtaining Financial Support
- STEP 3 Organizing the MSP Process
- STEP 4 Engaging Stakeholders
- STEP 5 Analysing Existing Conditions
- STEP 6 Analysing Future Conditions
- STEP 7 Developing the Plan
- STEP 8 Implementing the Plan
- STEP 9 Evaluating Performance
- STEP 10 Adapting the Process

Figure 9 Steps for developing and implementing marine spatial planning. Source: Intergovernmental Oceanographic Commission, 2009.

What we mean by marine spatial planning?

Governments are in the best place to establish how to balance the use of their seas and lead MSP. The offshore wind industry will continue to work with governments and other stakeholders to find the solutions that work best for a country.

MSP brings together users of the ocean – including energy, industry, government, conservation and recreation – to make informed and coordinated decisions about how to use marine resources sustainably.

The Intergovernmental Oceanographic Commission of UNESCO has published a step-by-step guide to MSP (see Figure 9).[24]

24 Marine spatial planning: a step-by-step approach toward ecosystem-based management, Intergovernmental Oceanographic Commission, 2009. http://msp.ioc-unesco.org/msp-guides/msp-step-by-step-approach/

Source: Ørsted

Lobster populations remain healthy in wind farm areas

Good quality data is vital in understanding how wind farms affect the environment and local businesses. Ørsted joined forces with the Holderness Fising Industry Group in 2013 to undertake a six year study on lobster populations near Bridlington in the UK, which lands 10% of all catches of European lobster.[25]

The study examined ecological effects on the shellfish species during construction and operation of Westermost Rough offshore wind farm. Results have shown that not only do stocks remain healthy, but also that no detectable impact has been identified for the shellfish. The study gives comfort to local fisherman concerned about the impact of wind farm on their livelihoods.

Colocation and coexistence

MSP can maximise the opportunity to co-locate or coexist. A 1GW wind farm takes up an area of about $200km^2$ and only a small proportion of this is actually taken up by the turbines, substation foundations, and cables. This is decreasing as the turbines used are increasing in power rating. Offshore wind projects with 12MW turbines typically have minimum separations between turbines of about 1.3 km, for example.

Offshore wind infrastructure such as turbines, substations, and cables need to be protected from accidental damage by other users, and the industry is committed to working with other sea users to find a way to co-exist.

Access to offshore wind farms by other users can be limited in practice, for example due to the risk of collisions or entanglement with cables or moorings. This is underpinned through regulation that often varies between countries. In certain jurisdictions this leads to some restrictions on marine activities. It is also recognised that offshore wind farms can introduce environmental benefits by creating new habitats and refuges.[26]

Some sectors, including tourism, have also already benefited from the establishment of local offshore wind farms.[27]

Synergies between sectors can include more efficient use of sea space and vessels, greater site security (for example reducing theft from fish farms), and provision of electrical power (to co-located users).

25 https://orsted.co.uk/media/newsroom/news/2020/07/lobster-populations-remain-healthy-as-wind-farm-study-results-are-published
26 Offshore Wind Energy - Draft Sectoral Marine Plan: Habitat Regulations, Scottish Government, December 2019. https://www.gov.scot/publications/draft-sectoral-marine-plan-offshore-wind-energy-habitat-regulations-appraisal/pages/9/appraisal
27 https://gwec.net/offshore-wind-energy-creates-opportunities-tourism-sector-south-baltic-region/

A pioneering wind farm and fish farm project

China Three Gorges plans to build a pioneering combined offshore wind and fish farming development in China's Bohai Bay. The 300MW Phase 1 Laizhou Bay wind farm will be completed in 2021. It will be first in China to set out to demonstrate the benefits of combining offshore wind and aquaculture technology. The first plan is to build six artificial reefs surrounding the turbine foundations to breed oysters, sea cucumbers and fish.

Shandong province is major seafood producer and it is hoped that the project can show that the industries can coexist, paving the way for further offshore wind farms in the province.

Source: Ørsted

CASE STUDIES

Floating wind powering oil and gas platforms in Norway

Equinor and the Snorre and Gullfaks oil and gas partners are investing in the Hywind Tampen offshore wind farm development of 11 turbines (88 MW). It will be located 140 kilometres from shore in 260-300 metres of water between the Snorre and Gullfaks platforms. Once it comes online in 2022, it will meet 35% of the annual power demand of the eight offshore platforms. This innovative project is the first to combine floating offshore wind with oil and gas and will offset 200,000t CO_2 emissions and 1,000 tof NOx every year.

Source: Øyvind Gravås, Woldcam, Statoil

Japan’s bidding process prioritises stakeholders

In supporting power projects, Japan gives a high priority to interests of the local business sectors, such as the fisheries and port industries. Offshore wind developers are therefore assessed on their ability to coordinate with these industries and on their impact on the local economy more widely.

The Japanese Government also has policies that encourage offshore wind users to coexist with local communities and the Government selects offshore wind zones based on a “bottom-up” approach to encourage greater contribution by offshore wind to the local economy.

The Hibikinada Offshore Wind Project started in August 2016, and the winning developer, Hibiki Wind Energy, was selected in February 2017. The choice of developer was based on the overall greatest value method, and 40% of the scoring marks were for the development, utilisation, and preservation of ports and the contribution to the port and regions.

Marine spatial planning leads to offshore wind and aquaculture feasibility projects

In May 2017, to explore the cultivation of mussels, a first experimental culture system was installed at the C-Power wind farm, located off the Belgian coast. This was followed by a second mussel culture system installed at the Belwind wind farm in November 2017. Both are being monitored to determine:

- Biological feasibility
- Technical feasibility and system requirements fit for heavy seas
- How best to integrate mussel farming with the existing activities in wind farms
- Profitability of commercial offshore mussel culture farming, and
- Sustainability of offshore mussel culture and the impact on seawater quality.

MSP has been a priority for Belgium because of the size of its territorial waters. In its marine spatial plan of 2014, 7% of Belgium’s territorial waters was allocated for offshore wind.

5. How can you best create jobs?

Jobs are created when the offshore wind industry invests. In working together, governments can create long-term, sustainable economic benefit and continue to drive down the cost of energy.

Job creation requires investment and investors prefer to see a long-term opportunity, and for offshore wind that means a strong and stable pipeline of projects.

The industry values the role that governments can play in supporting local companies to excel. Everyone benefits from the development of world-class skills and supply chains.

Sustainable jobs

We want to see a supply chain that is sustainable and provides long term work.

The manufacturing and installation jobs for a given project last for a short period, typically peaking over a three-year period. If these jobs are to be sustainable, companies need to find work supplying other wind farms. A healthy long-term pipeline of projects can provide that work. Investment – and therefore jobs – will flow from a critical mass of projects each year.

Jobs during wind farm operation last the whole of the wind farm's life, which can be 25 years or more, providing great stability as more and more projects come online.

About three quarters of the jobs relate to manufacturing and installation and about a quarter to operation. The development of global supply chains mean that operation will be the biggest source of new local jobs in many places.

The bigger picture

Offshore wind has been successful in reducing costs and creating jobs because it has drawn on the capabilities of the supply chain in different countries.

If each country plays to its strengths, it creates a more competitive supply chain and lowers investment risks (see North Sea cluster case study).

Local communities want sustainable jobs. The offshore wind industry provides these where local companies compete successfully on cost and quality and can supply offshore wind farms regionally and globally. The most successful companies are those that look beyond the wind farms being built in their area and see an opportunity to add value in global markets.

Cost reduction has been key to the industry's success, but often learning and innovation reduce costs by reducing the work needed. While the number of jobs created per MW of capacity drops, more jobs overall can be created because cost reduction can mean a bigger market. An excessive focus on local jobs can slow cost reduction and hence lead to fewer projects being built and can creating fewer jobs.

The balance between local content and cost

A good government strategy creates an environment where the industry can thrive and create long-term jobs while reducing cost of energy, rather than promoting local content at the expense of cost.

Mandating local content requirements can lead to uncompetitive supply chains that cannot export successfully and the closure of factories as soon as the local requirements end or the local market slows temporarily. We want to support the development of long term sustainable job creation that makes lasting improvements to local economies by growing competitive supply chains.

Competitive supply chains

In new markets, investors need the confidence that the market will endure. Components such as blades, towers and foundations are likely to be localised first in a new market because they are expensive to transport and do not have complex supply chains. In contrast, turbine nacelles have many hundreds of components and a new assembly plant is a major strategic decision for a supplier, introducing many new logistics and quality challenges.

Supply chains may take time to develop. 'Pathfinder' projects with a gradual increase in project size can ensure that learning is developed and sustained by the local workforce.

Local clusters, such as those in Bremehaven (Germany) and Grimsby (UK), play a vital role in developing competitive supply chains. The best examples are where there are partnerships between local government and businesses in a location with strong geographical logic to support the needs of the industry.

Source: JERA

Source: Global Marine Group

An industry-driven regional supply chain cluster

The offshore wind supply chain is most mature in northern Europe. While governments have sought to maximise their national economic benefit from offshore wind, they have generally tried to achieve this by supporting investment that helps them become competitive across the region.

The key markets of Belgium, Denmark, Germany, Netherlands and the UK have all seen significant industrial investment. Denmark and Germany have historical strengths in turbine components and the major suppliers have invested, along with their supply chains. In the Netherlands and Belgium, strengths in marine contracting and heavy steel fabrication have been built on their suppliers' lead the industry.

In the UK, the key investments have been in blade manufacture and, as Europe's leading market, there have been significant investments in operational infrastructure. Many successful companies have a background in the offshore oil and gas industry.

Fuelling demand for offshore wind

Guangdong Province is one of the most economically active regions in China and the demand for energy, especially clean energy, continues to expand.

Guangdong Province plans to install 66GW of offshore wind capacity by 2030. Yangjiang City aims to benefit from the growth of the industry and has developed the largest, integrated wind power manufacturing cluster in the APAC region.

The government designated a 740 hectare area for offshore wind and has attracted investment from 21 domestic and foreign companies, including CRRC Electric, Goldwind, Mingyang Smart Energy, SSB Wind and Three Gorges New Energy. The site hosts turbine assembly; blade, tower and foundation manufacture; project construction; and operations and maintenance.

When completion, the annual output value of the base is expected to reach $17.2 billion, creating 50,000 direct jobs.

If the market is there, the jobs will follow

According to IRENA, a 500MW wind farm creates directly 2.1 million person days of work or about 10,000 person years. For 1.4TW, this could mean the creation of almost 30 million person years of work. About a quarter are in operations.

The components and services needed to develop and build a wind farm only support jobs for a short period, but many stable jobs are created over the 25-30-year operating life of a project. Local skills are always needed because the workforce needs to live close to the wind farm or because the wind farm needs local knowledge of the environment or the planning system. These workers are generally highly trained and well paid. The more wind farms that are built, the more local jobs will be created.

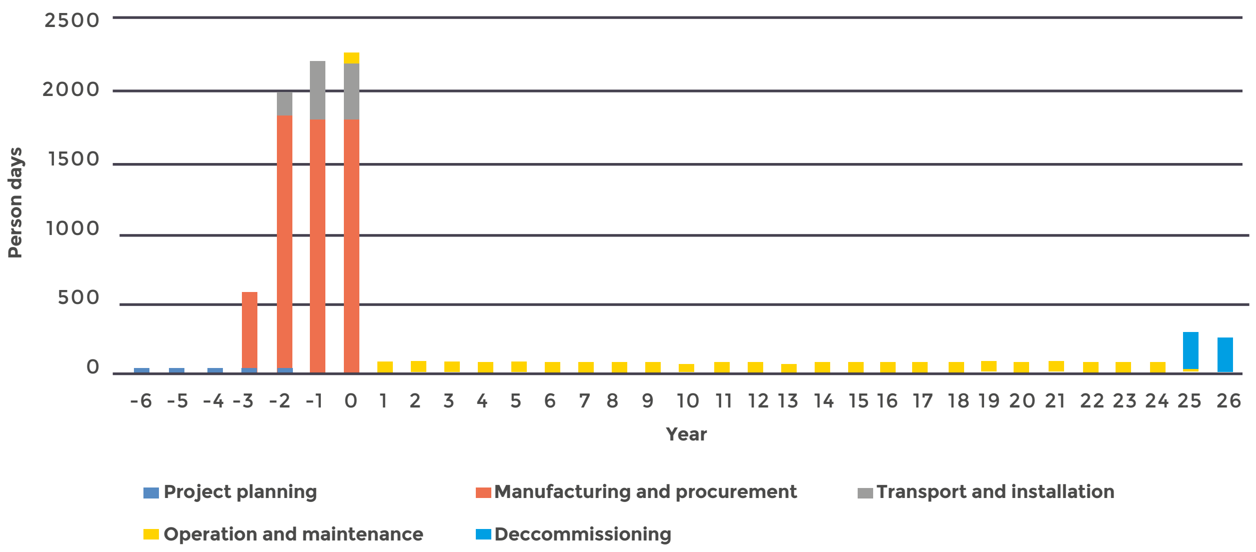


Figure 10 Jobs created for a 500MW wind farm.

The path to local industrialisation

A typical viable factory for a range of components is 100 units a year. An annual market (national or regional) of 2-3GW will probably be needed to give an investor confidence it can win sufficient orders in a competitive market. Being a first mover can be a big advantage and provides an opportunity to export to other markets in the region.

Phase I
New market needing fewer than 100 units a year

- All components are likely to be supplied from established factories
- Local jobs from development, construction support and operations

Phase II
Established market needing 100-200 units a year

- Most components from established factories
- Potential local supply of towers and foundations

Phase III
Mature market needing more than 200 units a year

- Significant components localised in regional market
- Potential additional supply of blades and nacelles although investors will consider regional market rather than each national market

Figure 11 path to local industrialisation.

CASE STUDIES

A highly skilled workforce

Industry will work with governments to develop the local skills needed. Offshore wind farms create high-value jobs, often in disadvantaged areas. The industry recognises the need for a just transition, and the industry will collaborate to reskill workers from other sectors. Offshore oil and gas and shipbuilding have significant transferrable skills, but other sectors have much to offer too. For example, ex-servicemen and women often have valuable technical and project management skills. The industry is committed to a developing a diverse workforce needed and many developers have set up community funds to support local skills development. For example, Ørsted has set up an East Coast Community Fund with a skills fund in the UK, which includes a hardship grants for disadvantaged students to undertake technical courses relating to offshore wind.

The industry creates high tech jobs in areas such as digitisation and material science; it also values partnerships with universities and companies to develop new technologies.

It can also stimulate investment in local education and training, and these can have benefits for other industries that need a well-trained technical workforce.

New employment opportunities for fishermen

In its heyday, Lowestoft was one of the North Sea fish capitals of the UK, but since the crash of the fishing industry, the town has suffered economic decline. In 2005, the government recognised the potential of offshore wind and the importance of the transition to low carbon energy sources, and facilitated the development of offshore wind farms, locally. Lowestoft's biggest asset and opportunity was its port infrastructure and proximity to the southern North Sea. The value of offshore wind to Lowestoft to date is about $4billion and this will reach $21 billion by 2030. The development will create 4,400 construction jobs and 300 long-term skilled jobs. In many instances, ex fishermen are now locally employed as skippers of crew transfer vessels that operate from the site of where Lowestoft's old fish market once stood.

6. How do we keep offshore wind safe?

Working in offshore wind requires effective risk management practices that ensure people and the environment are protected. The offshore industry goal is to get it 'right first time', and this is achieved by anticipating mistakes and building safeguards into the systems, creating a sustainable capacity to deliver safely and reliably.

A culture of health and safety

Health and safety in the offshore wind industry is not only a top priority but also a pre-condition to safe, reliable operations in the offshore environment. The industry works to embed health and safety as a value in the culture of organisations so that everyone takes responsibility and cares for one another.

Offshore wind companies' first aim is to embed safety into equipment designs and eliminate hazards wherever possible, such as working in confined spaces. If it cannot remove a hazard, the industry mitigates risks to the fullest extent practicable.

Between 2015 and 2018, the total recordable injury rate per activity fell by 22% globally and the lost time injury frequency fell by 17%.[28]

The mental health of offshore workers is a key aspect of health and safety who may need to spend time away from their families.

Learning in the sector and from other sectors

Many companies have transferred proven health and safety practices from oil and gas and other maritime industries. The offshore wind industry has built on these methods and developed collaborative approaches to meet its needs and ensure continuous improvement and learning.

Offshore wind has some distinct challenges from other maritime sectors. Specialised technicians work in small teams and access turbines regularly during construction and operation, often in rough conditions. They work with large complex pieces of equipment and at substantial heights.

An important innovation has been the introduction of service operation vessels (SOVs). These vessels provide an offshore base for wind farm workers. Offshore wind technicians may be new to working at sea and SOVs avoid the long journeys from shore which can make technicians unwell due to motion sickness. SOVs offer technicians 'no-step' or 'walk to work' access when transitioning from an SOV to a turbine or another offshore structure. The SOV working deck also allows for simplified transfers of tools and spare parts to the work area.

28 Data from G+.

Collaboration across industry

The industry maintains regularly updated good practice guidelines, facilitates conferences and workshops together with external stakeholders, regulators and interested communities to share health and safety information and build strong partnerships.

The Global Offshore Wind Health and Safety Organisation, G+, brings together the offshore wind industry to pursue shared health and safety priorities. Companies new to the offshore wind industry are encouraged to join and actively engage with existing industry networks by committing their support and contribution to the delivery of excellence in health and safety.

Innovation for safety

As the industry continues to grow, it recognises the need for continual performance improvement and to ensure the high reliability of organisations in conducting their operations safely. In addition, the industry is constantly evaluating improved methods to assess the effectiveness of safety systems, monitoring health and safety performance in real-time and innovating to manage known and emerging risks to people and the environment

Innovation in offshore wind has not only helped to drive down the cost of energy but has also enhanced safety. Subsea inspection of turbine structures and foundations can now be undertaken using autonomous vehicles, removing the need for vessels or technicians to mobilise and operate offshore. This eliminates the safety risks of having people under water, minimizes potential impacts to the environment and reduces operating costs. Turbine reliability continues to improve through advancements in equipment design, quality, selection and programmes used to ensure the integrity and reliability of offshore equipment. This has decreased the overall number of service visits to offshore wind turbines, further reducing health and safety risks to workers and the impacts on the marine environment.

CASE STUDIES

A global collaboration to enhance health and safety

The G+ Global Offshore Wind Health and Safety organisation membership includes ten of the world's largest offshore wind farm developers.

The G+ has three main work areas:

- Incident data reporting
- Good practice guidance, and
- Safe by design workshops.

The Focal Group consists of members' health and safety experts, who meet monthly to deliver the work programme of G+. There are European and APAC Focal Groups, with consideration currently being given to creating a North American Focal Group. These groups also hold stakeholder events to discuss health and safety challenges facing the sector and help shape the organisation's forward work programme.

New technology to improve safety

Blade inspections are critical in the maintenance of offshore wind farms, helping operators assess the condition of their assets. The conventional method of inspection using rope access has inherent risks associated with working at height and in confined hazardous environments.

Unmanned aerial vehicles (UAVs) are becoming the go-to method for inspection across the wind industry. UAV technology provides a means to reduce the risk of inspection tasks, increase the frequency of inspection and provide high-quality information for the maintenance planning process.

Cyberhawk is one of the service providers leading the way in the area of UAV inspection and its safety record proves that this technology is a safe alternative to rope-access with zero lost-time injuries in 290,000 hours.

A step change in offshore wind safety

Accessing offshore wind turbines is traditionally via a crew transfer vessel (CTV). The CTV essentially 'pushes on' to the foundation of the turbine and the technician accesses a ladder and climbs onto the turbine platform. At higher wave heights, this operation carries increased risk, or cannot be completed.

An industry response has been to deploy service operation vessels (SOVs). Equinor, using its years of experience from oil and gas in the North Sea, was the first offshore wind operator to employ an SOV in the UK at the Dudgeon Wind Farm. SOVs provide a 'walk to work' moveable gangway system enabling safer access for technicians at higher wave heights than with a CTV. It also provides safer lifting operations. This is also an example where improved safety can also lead to improved operations and higher operational availability of the wind turbines.

A safety legacy for the Humber region

Ørsted has recently partnered with safety leadership innovators Active Training Team (ATT) and the training centre MODAL, to build a cutting-edge learning centre that will benefit several industries across the Humber region in UK. It will provide training programmes designed to bring about transformational behavioural change in attitudes to safety. The facility will first deliver induction days developed for the construction team working on Ørsted's latest offshore wind farm, Hornsea Two, which will be the world's largest wind farm when it comes online in 2022.

Source: Ørsted

7. How do we manage the impact on the environment?

The offshore wind industry strives to develop offshore wind in a sustainable manner, considering economic, social and environmental impacts. As well as producing clean energy, the industry is committed to avoiding, reducing and, where relevant, mitigating significant negative disturbance on the marine natural environment.

In Chapter 1: What can offshore wind do for your country? we showed that offshore wind has many environmental benefits: it saves carbon, reduces water consumption and reduces air pollutants. Like any human activity, however, offshore wind will have an impact on local ecosystems. These benefits are aligned with the UN's Sustainability Goal 12 to promote responsible consumption and production and Goal 14 to conserve and sustainably use the oceans, seas and marine resources.

The industry welcomes the role of governments in building a comprehensive picture of marine users' impact on the environment. If the environmental impacts of wind farms are not considered fully at an early stage, a project may be cancelled during development. This can be costly and make it harder for a country to achieve its targets for the sector. Marine spatial planning provides a robust framework for achieving this.

Chapter 4: How do we coexist with other marine uses? describes how the industry will work with governments to develop projects responsibly.

The offshore wind industry undertakes appropriate management of the impacts of its activities on the natural environment in three ways:

- By avoiding, limiting or mitigating local significant negative impacts on the natural environment during construction, operation and decommissioning in line with relevant national or international requirements
- By exploring opportunities to maximise the use of recycled materials during manufacturing, and
- By exploring opportunities to maximise the re-use and recycling of components after decommissioning.

The industry understands that there are genuine concerns about the impacts of wind farms on the natural environment. These impacts will depend on the local populations and ecosystems. Each country will therefore develop its own solutions and standards to avoid, minimise or mitigate these effects and also consider international standards, conventions and other regulations. Established markets have developed strategies which may provide useful lessons learned; however; it is important that site specific assessments continue to identify and adapt to local conditions and stakeholder requirements.

Valuable work by governments, as part of the permitting processes or marine spatial planning, at an early stage, can consider the cumulative environmental impact of several wind farms. This approach benefits the natural environment as it can be best protected with actions informed by good data. It also benefits developers by lowering their permitting risk.

Technology development to reduce the cost of energy can also lead to opportunities for the natural environment. With larger turbines, fewer may be needed to achieve a given wind farm capacity and they are spread further apart. This increases the space between turbines and can reduce the overall magnitude of some impacts. Wind farms, which can be as far away as 150km from a grid connection point, typically use high voltage direct current, which requires fewer cables and therefore potentially less disturbance along the export cable route during installation.

Creating new habitats

Offshore wind farms can also have beneficial impacts on the natural environment. Turbine and substation foundations provide new structure which can act as artificial reefs and refuge habitats. Some wind farms have installed additional structures to support wildlife. As part of the Rich North Sea collaborative agreement in the Netherlands, 'nature inclusive design' is a requirement for all new wind farms and structures are being deployed in and around wind farms to introduce such new reef habitats.

CASE STUDIES

Cumulative environmental impacts at the heart of offshore wind strategy

The Netherlands 1998 Nature Conservation Act requires projects to assess not only their direct adverse effects but also their cumulative effects in combination with other plans and projects. In 2019, the Rijkswaterstaat, the Netherlands Directorate-General for Public Works and Water Management, published its Framework for Assessing Ecological and Cumulative Effects. The basis of the framework was the 2030 Offshore Wind Energy Roadmap that was published in March 2018. This included the timetable and location of the wind farms at sea up to and including 2030.

The Framework specifies the approach for identifying and describing cumulative effects and how these relate to offshore wind energy. It also describes the important steps in calculating the effects of implementing the offshore wind roadmap.

Mitigating impacts on marine mammals

Piling noise, which occurs during the installation of the foundations, can affect the behaviour of marine mammals and fish. The industry has worked to reduce noise levels or avoid sensitive times in areas where such sensitivities exist. In Germany, for example, there can be a requirements for marine contractors to use bubble curtains to reduce underwater noise propagation. In other markets specific procedures of piling timing and marine mammal observations are used. The industry and the supply chain works closely together to look at how technologies can be matured and applied in regulatory settings to look at options for minimising significant noise impacts.

Reducing the carbon footprint of operations

In June 2019, the UK Government passed a law to end its contribution to global warming by 2050. The target requires the UK to bring all greenhouse gas emissions to net zero by 2050. The maritime sector contributes approximately 3% of global emissions and is an important area for the industry to tackle.

CWind has developed a hybrid surface effect ship, a CTV which will be in operation in 2020 at Ørsted's Borssele offshore windfarm. The vessel's development was supported by the Carbon Trust Offshore Wind Accelerator, a collaboration between developers to support innovation in the industry.

Future developments could lead to electric vessels using hydrogen fuel cells and energy-dense batteries.

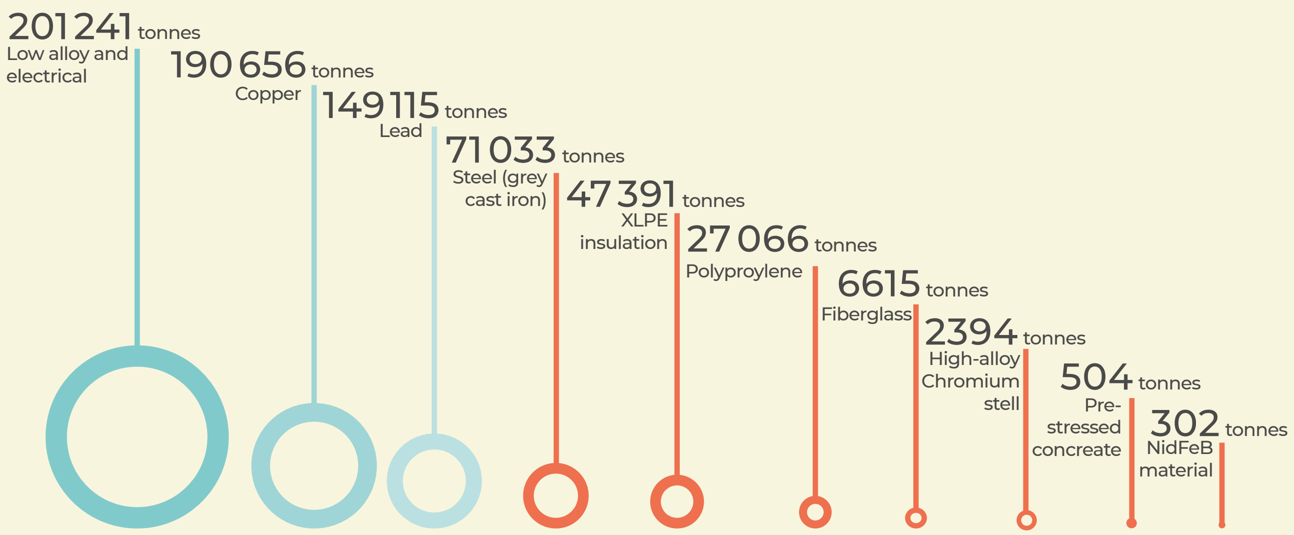
Source: MingYang Smart Energy

Source: GE Renewable Energy

Life extension, re-use and recycling

The offshore wind industry is becoming more sustainable by increasing the operating life of wind farms. Early offshore wind farms used adapted onshore machines that were built with a 20-year design life. The first dedicated offshore turbines were designed for 25 years and many wind farm owners confidently expect their wind farms to operate for 30 years.

At decommissioning, there is likely to be a good case for repowering the wind farm with new turbines. With the growth in turbine size (and therefore spacing), most of the wind farm will need to be replaced but there are likely to be opportunities to re-use or upgrade the transmission infrastructure.
As a relatively young industry, very few wind farms have reached the end of their lives. Ørsted's Vindeby offshore wind farm was the first multi-turbine offshore wind farm in the world, erected in 1991 off the coast of Denmark. It was decommissioned in 2017 after 25 years of useful life. A significant potion of the turbine can be recycled, and historically, blade materials have only had low grade uses, but there are now several initiatives underway to better re-use composite materials.



Note: NidFeB material (also known as neodymium magmet, NIB or Neo magnet), is a permanent magnet made from alloy of neodymium, iron

Figure 12 Materials in a 500MW offshore wind farm.[29]

29 Renewable Energy Benefits Leveraging Local Capacity for Offshore Wind, IRENA, 2018

8. What other technologies can be used to harness ocean-based renewable energy?

Emerging ocean-based renewable energy technologies can a play a significant role in maximising the ocean's contribution to carbon reduction. Key emerging sources of ocean renewable energy are wave and tidal energy.

The opportunity from emerging ocean-based renewable technologies

Emerging ocean-based renewable technologies can become affordable solutions in many countries across the world. In these countries, they can become significant contributors to a reliable and flexible energy portfolio. The Technology Collaboration Programme for Ocean Energy Systems (OES) has a vision in which 0.3TW of these emerging technologies are installed by 2050, creating 680,000 jobs.[30]

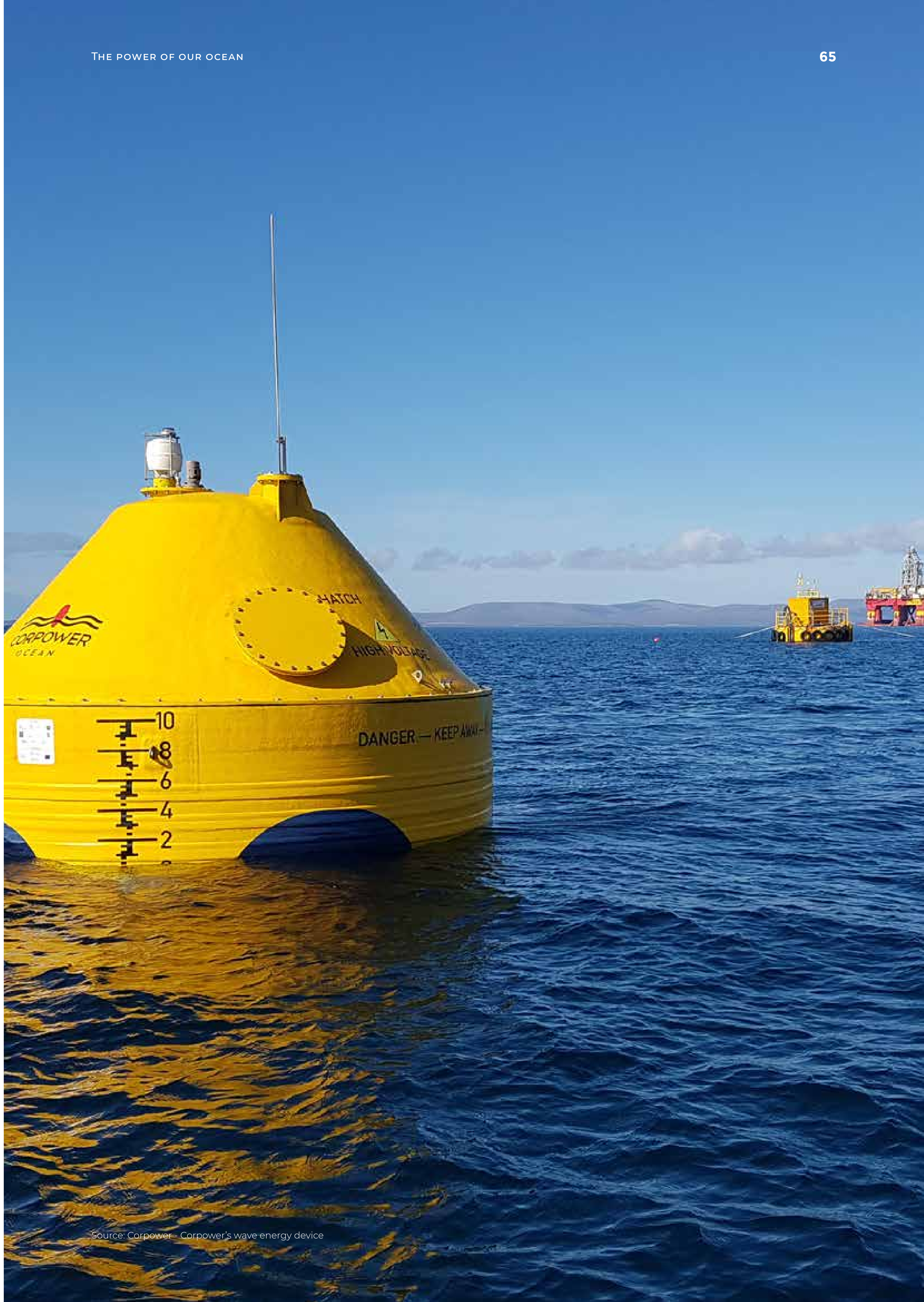
There are five main types of technologies considered in this chapter:

- Tidal currents
- Tidal range (rise & fall),[31]
- Waves
- Ocean thermal energy and
- Salinity gradient.

These technologies have many benefits. They reduce carbon emissions, save water, improve air quality, create new opportunities for economic development, and enhance energy security and independence.

Many countries with island or remote populations are dependent on expensive and polluting diesel generation. Emerging ocean-based renewables are well suited to provide off-grid solutions.

30 An International Vision for Ocean Energy, 2017, Technology Collaboration Programme for Ocean Energy Systems
31 Today range technology is further established than the other emerging technologies described here



Source: Corpower – Corpower's wave energy device

Source: Laminaria - Laminaria's wave energy device

Wave energy

Wave energy has significant potential because of the global scale of the resource. The challenge comes from devices needing to generate efficiently in a wide range of normal conditions, whilst surviving in occasional extreme conditions.

There are a many demonstration projects worldwide with many different concepts being explored.

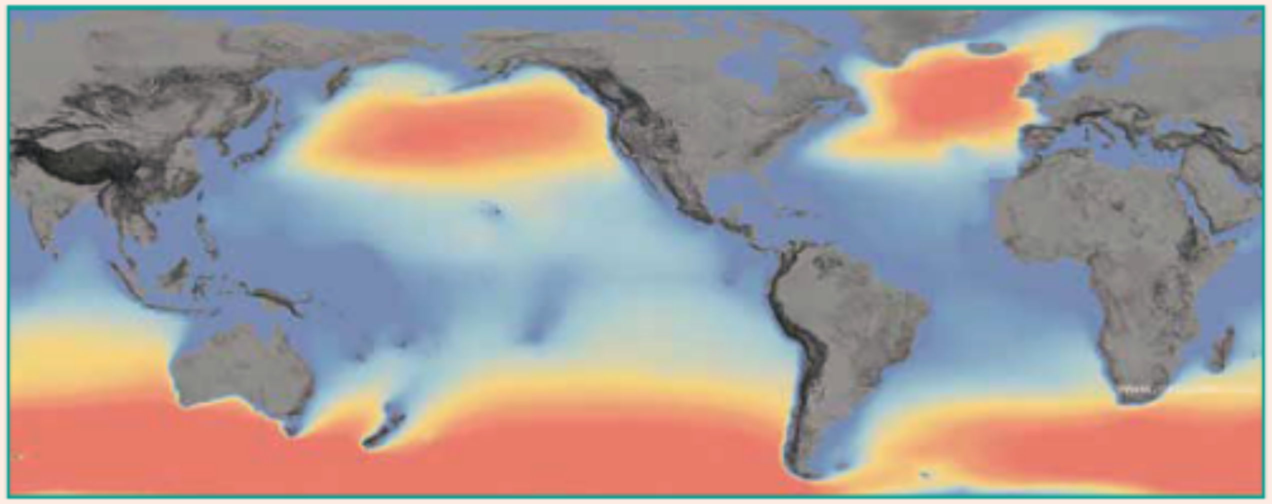


Figure 13: World distribution map of wave power. Source: OES

Wave Power (kW/m)
0 25 50 75 100 125

Ocean thermal energy

In the tropics, the temperature of surface seawater may be 20°C higher than deep ocean water. Bringing large quantities of this cold seawater to the surface enables a heat exchange process with the warmer surface waters, from which energy can be extracted.

Demonstration projects are now operating in Japan and Hawaii.

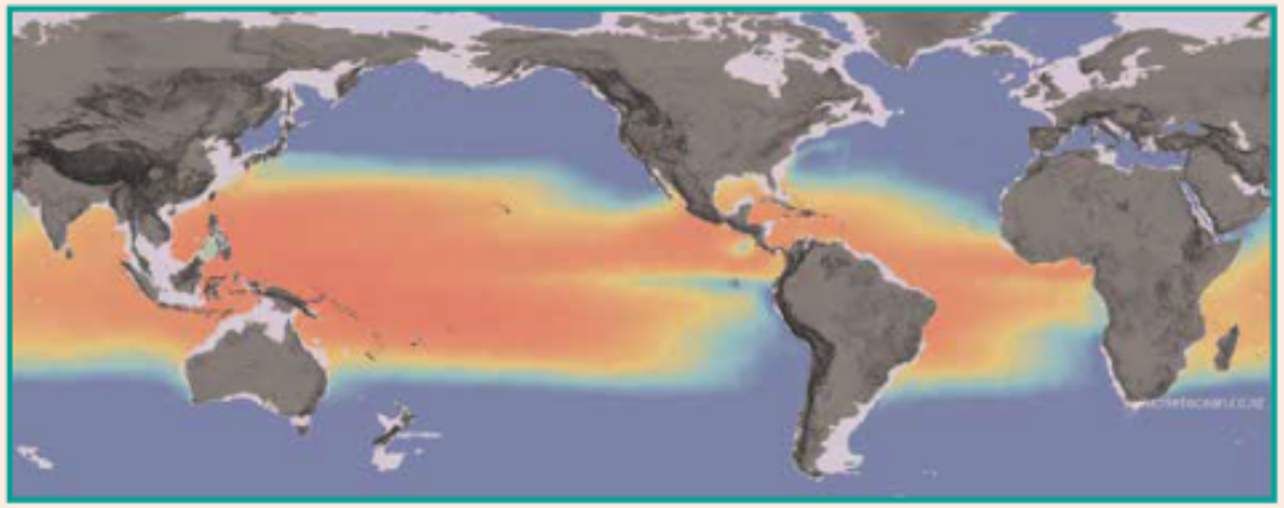


Figure 14: World distribution map of OTEC. Source: OES

TEMPERATURE DIFFERENCE 20-1,000 m (Deg C)
Areas < 1.000 Water Depth
15.0 17.5 20 22.5 25

Tidal current energy

The movement of ocean water volumes, caused by the changing tides, creates tidal current energy. Kinetic energy can be harnessed, usually nearshore and particularly where there are constrictions, such as straits, islands and passes. Because tides can be predicted with accuracy, so can the energy generated.

Tidal current energy uses similar concepts to wind energy. Challenges arise due to the harsh environment where the resource is greatest, moreover, there are limited appropriate locations for this technology. This has meant that innovative solutions have been developed that requires lower tidal resource in more locations.

The first tidal current array, Meygen, is now operating with four 1.5MW devices off the north coast of Scotland.

Tidal range energy

Tidal range energy is derived from height changes in the sea, caused by the gravitational attraction of the moon. While the tidal range is not noticeable at sea, it becomes amplified close to shore. The rise and fall of the tide offers the opportunity to trap a high tide, delay its fall behind a barrage and then capture the energy before the next tidal cycle via water turbines.

Tidal range technology is mature, and facilities are being increasingly deployed in China and Korea.

Salinity gradient power

Seawater has salinity values around 30-50 ppt (parts per thousand), whereas fresh water has values of less than 0.5 ppt. This creates chemical pressure potential between sea water and fresh river water as it runs into the sea. This leads to water flow across the gradient, which can be harnessed to produce energy.

Source Orbital Marine Power - Orbital Marine Power's Floating Tidal System

What can other emerging renewable energy do for your country?

Emerging technologies have emerging supply chains. This creates opportunities for countries to gain first-mover advantage, by nurturing new, smaller industries with export potential. The smaller scale of the industry may be better for some supply chains. Offshore wind established on the back of an already global onshore wind industry, whereas wave and tidal activity is still at a scale where smaller players can play a leading role.

The wave and tidal resources vary significantly across the world. Countries can develop solutions that are optimised for their resource. This creates local opportunities for local companies, with local jobs for communities. Investment in innovation can lay the foundation for a sustainable and competitive supply chain.

Emerging technologies can further enhance the energy security and independence provided by offshore wind. The energy profile and characteristics are different and therefore improve grid resilience and reduce the need for energy imports.

What is the best way to realise the benefits of other ocean renewable technologies?

Other than tidal range energy, emerging technologies are at pre-commercial stages. Figure 11 shows the status of the different technologies.

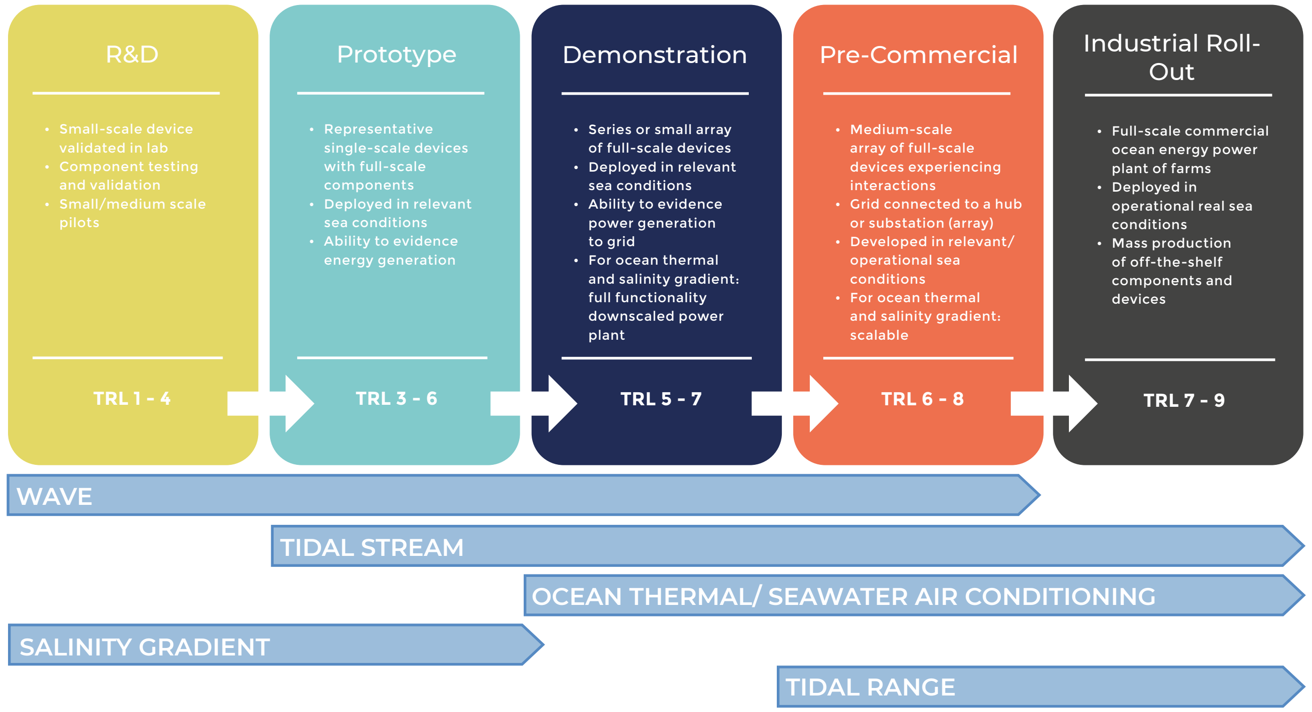


Figure 15 Potential and commercial readiness of emerging ocean renewable technologies. Source: OES

Emerging technologies need to reduce the cost of energy to make them competitive with more established technologies, but cost reduction does not happen by itself. It needs a combination of technology push and market pull. There are a range of technology challenges (see Figure 12) but all are focused on the need to reduce cost of energy while operating in harsh marine environments.

Innovation will be a vital part of these technologies' emergence. Offshore wind has learned that the greatest progress can be made when innovation is led by demand. For wind, developers provide that demand from their pipeline of projects. For emerging technologies, commercial projects are not in development. Governments and their research and technology organisations can play a vital role in creating the demand. International collaboration can play an important in accelerating the commercialisation of innovations.

Some other actions that governments can take to accelerate emerging technologies are shown in Table 1.

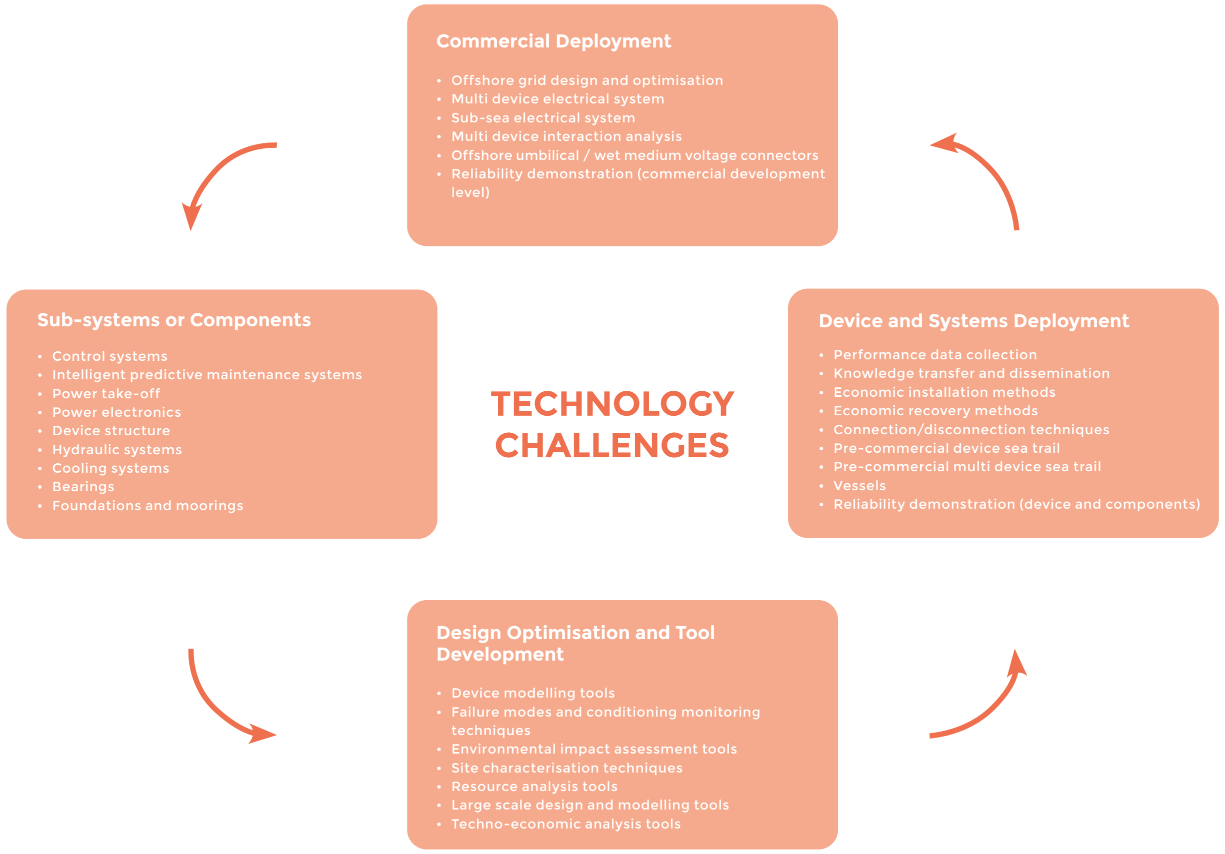


Figure 16 Technology challenges for emerging ocean renewable technologies. Source: OES

THEME	POLICIES	DESCRIPTION
Capacity or Generation Targets	Legislated targets	National targets for total energy or electrical production
	Aspirational targets and forecasts	Non-legislated targets or forecasts for deployment of ocean energy technologies
Capital Grants and Financial Incentives	R&D programmes / capital grants	Grants to encourage innovative research into ocean energy technologies
	Prototype development capital grants	Grants to encourage deployment of prototype devices
	Project development capital grants	Grants for deployment of projects (usually matching funds)
	Prizes	Prizes for achieving production targets from protype devices
Market Incentives	Feed-in tariffs	Guaranteed price (in $/kWh or equivalent) for ocean energy generated electricity
	Tradable certificates and renewable obligations	Legislated requirements for electricity generators to invest in ocean energy-generated electricity
	Tendering processes	Tendering for capped supply from ocean energy-generated electricity
Industry and Supply Chain Development	Industry and regional development grants	Cluster developments
	Industry association support	Government financial support for establishment of industry associations
Research and Testing Facilities and Infrastructure	National marine energy centres	R&D and deployment centres
	Marine energy testing centres	Testing centres for prototype and pre-commercial device trials
	Offshore hubs and pilot zones	Consented sites with connection infrastructure for devices
Resource Allocation and Industry Standards	Standards/protocols	Development of international standards for wave, tidal and ocean currents
	Permitting regimes	Crown Estate competitive tender for Pentland Firth licenses
	Space/resource allocation regimes	Department of interior permitting regime in United States Outer Continental Shelf

Table 1 Actions that governments can make to accelerate the commercialisation of emerging ocean-based energy technologies.

Market pull is the other essential ingredient. Without it there is no case for investment in technology and supply chain. A long-term vision from governments is therefore vital. Emerging ocean-based renewables need clear, strong and long-term policies to grow the sector. The wind industry's ability to compete with all forms of energy generation resulted from decades of commitment from countries such as Denmark and Germany.

This in turn needs to be based on a reasonable expectation that the technologies will deliver. OES concludes that 10GW of wave and tidal current energy installed could reduce the cost of energy by factors of 10 and 3, respectively.[32] It is important that the emerging industries provides clear pathways for cost reduction and supply chain development.

32 An International Vision for Ocean Energy, 2017, Technology Collaboration Programme for Ocean Energy Systems

CASE STUDIES

An ambitious framework for tidal current generation

Nova Scotia in Canada has one of the most ambitious tidal current strategies. This seeks to harness its significant tidal resource. About 160 billion tonnes of water flows through the Bay of Fundy each tide, equal to four times the estimated flow of all the freshwater rivers in the world combined.

Nova Scotia aimed to have installed 300MW by the end of 2020. The target is underpinned by the 2015 Marine Renewable Energy Act which provides a clear, predictable and efficient process to support the sustainable growth of the sector.

A vital part of the strategy is a feed-in tariff that makes progress commercially attractive for developers. An important feature is the different rates for small and large projects and for testing.

So far, five developers have received approval through the programme for a total of 22MW of capacity.

Source: CrestWing- CrestWing's wave energy device

A unique wave and tidal energy test site

Established in 2003, EMEC is the first and only centre of its kind in the world to provide developers of both wave and tidal energy converters with purpose-built, accredited open-sea testing facilities.

EMEC is based in Orkney in Scotland, which is an ideal base with its excellent wave regime, strong tidal currents, grid connection, sheltered harbour facilities and the renewable, maritime and environmental expertise that exists within the local community.

There are 13 grid-connected test berths and there have been more marine energy converters deployed at EMEC than at any other single site in the world.

EMEC also operates two scale test sites where smaller devices, or those at an earlier stage in their development, can gain real sea experience in less challenging conditions than those experienced at the grid-connected wave and tidal test sites.

Appendix A: Offshore wind market readiness assessment

This self-assessment tool is to assist policy makers, regulators, market enablers and key industry players in developing an offshore wind market. This appendix includes an overview of the tool and sample sections of the tool.[33]

The tool has been designed for use at country scale but it can also be used at regional or state/province scale or can additionally refer to those perspectives during the assessment. For further information, and the complete toolkit, visit GWEC's website at https://gwec.net/

The assessment is best undertaken by a team of people in a facilitated workshop.[34]

How to use the tool:

1. Identify a cross-section of experienced people who have an interest in one or more of the 12 practices, and who together cover all the practices in Table 2.
2. Work through the model practice-by-practice, starting at Level 1, and working up the levels until most statements are no longer true. At a level where some descriptors are true and others are not, note the strengths (e.g. for Health & Safety, we are at Level 2 with two elements of Level 3 and one at Level 4).
3. Consider the evidence for your chosen level. At Levels 3-5 this evidence should be in document form. Record the 'score' for each of the twelve practices:

(Level 1 = Foundation; Level 2 = Average; Level 3 = Good; Level 4 = Excellent; Level 5 = World Class.)

Looking back at all twelve levels, chose four you see as priorities for improvement for the country and identify an target score, two years from now, for each of these.

The next two pages give examples of the first two topic level descriptors and scoring.

33 For further information, and the complete toolkit, visit GWEC's website at https://gwec.net/
34 This self-assessment framework follows the approach outlined in the book No More Consultants by Geoff Parcell and Chris Collison, 2009

Topic	Level	Target	Target Date
1. Policy			
2. Stakeholders			
3. Legal			
4. Health and safety			
5. Consenting and permitting			
6. Grid connection			
7. Offtake and revenue			
8. Projects			
9. Equipment and services supply			
10. Finance			
11. Installation and commissioning			
12. Operation and decommissioning			

Table 2 Range of expertise needed for an offshore wind market readiness workshop.

Policy

Policy is closely linked with political aspiration for renewable energy deployment and aspiration can be measured in terms of capacity targets and financial support. Many supportive policy measures can be readily put in place by government, but they can also be rescinded. Stability of offshore wind policy is important and provides security to underpin investment. Long term legislated positions have greater weight than policy alone. Support regimes must reflect the maturity of the market - new and/or isolated markets need greater support.

Level	Description
World Class (5)	1. Policy exists for offshore wind deployment forward for 10 years or more 2. The policy is supported by all major political parties 3. Established financial support regime is clear including grants, feed-in tariffs, power price premiums (or equivalents) 4. Demand for offshore wind is explicit in policy, either as GW, TWh or quantity of financial support 5. Financial support is sufficient for the country or region (score both) exceeding 4GWpa of offshore wind (no less than 400 turbines) 6. Local content rules do not obstruct deployment 7. Carbon reduction commitment anchored by legal framework 8. Policy committing to zero carbon emissions from the power sector by 2050 9. All policy in support of offshore wind is thorough, coherent and aligned 10. Robust Marine spatial planning process complete with reliable characterisation information available
Excellent (4)	1. Policy exists for wind power deployment forward for 7 years or more 2. The policy is supported by most major political parties 3. New financial support regime is clear including grants, feed-in tariffs, power price premiums (or equivalents) 4. Demand for wind power is explicit in policy, either as GW, TWh or quantity of financial support 5. Financial support is sufficient for the country/region exceeding 2GWpa of wind power 6. Local content rules increase levelised cost of energy 7. Policy committing to 80% reduction in carbon emissions from the power sector by 2050 (based on 1990) 8. Most policy in support of offshore wind is thorough, coherent and aligned 9. Robust marine spatial planning process complete, no characterisation data available

Level	Description
Good (3)	1. Policy exists for renewable power deployment forward for 5 years or more 2. The policy is supported by the two main political parties (in majority) 3. Financial support regime is expected in next 2 years including grants, deed-in tariffs, power price premiums (or equivalents) 4. Demand for renewable power is explicit in policy, either as GW, TWh, g/kWh or quantity of financial support 5. Financial support is sufficient for the country/region exceeding 1GWpa of renewable power 6. Local content rules are challenging from lack of supply chain 7. Policy committing to 50% reduction in carbon emissions from the power sector by 2050 (based on 1990) 8. Marine spatial planning is underway but incomplete
Fair (2)	1. Policy exists for low carbon power deployment forward for less than 5 years 2. Financial support is insufficient to invest in low carbon projects 3. Demand for low carbon power is not quantified in policy 4. Local content rules are restrictive e.g. requiring supply chain commitments
Foundation (1)	1. Limited low carbon energy policy and no more than minority government support to policy 2. No clear expression of demand for low carbon power generation

Stakeholders

Having a full suite of testing, challenging and engaged stakeholders should be broadly encouraged as it has been shown that stakeholder challenge reduces development risk in the long run.

Seeking to avoid, bypass or supress stakeholder views does not work. Government and developers can be encouraged to build stakeholder knowledge, engagement, support, and in some cases improve resource availability. Industry groups are a strong tool in this regard and also an excellent measure of the health of the stakeholder ecosystem.

Insufficient stakeholder resource is an ongoing issue across many markets and should be high on governments list of actions, it has a high cost benefit balance.

Engagement takes time, can result in delay and is difficult, as such a mandated process of engagement early in the development cycle makes the process easier to complete and adds value.

Source: Ørsted

Level	Description
World Class (5)	1. Stakeholder ecosystem covering all areas 2. Stakeholders well informed, educated and experienced in the offshore wind industry 3. Stakeholders sufficiently resourced and funded to proactively support and strategically guide offshore wind deployment 4. Stakeholders mandated to support process at appropriate timescales 5. Clear, mandated, structured and embedded engagement process. Process well understood 6. Embedded and functioning industry groups exist covering all areas 7. Highly active and supportive lobby groups (such as Friends of the Earth and Greenpeace); No anti-groups 8. Independently documented strong public support for offshore wind
Excellent (4)	1. Stakeholder ecosystem covering most areas relevant to offshore wind 2. Stakeholders with background and experience in the offshore wind industry 3. Stakeholders have resource but limited funding to proactively manage offshore wind deployment, some delays possible 4. Stakeholder engagement process understood, supported and structured 5. Embedded and functioning industry groups exist covering most topics / areas 6. Active supportive lobby groups . Few anti-groups 7. Independently documented public support for renewables
Good (3)	1. Stakeholder ecosystem covering key areas relevant to offshore wind 2. Stakeholders with some background or experience in offshore wind industry 3. Stakeholders have resource but constrained depending on volume, not proactive and potential for delay 4. Stakeholder engagement process understood, supported and required, not well structured 5. New or establishing industry groups exist covering key areas only
Fair (2)	1. Stakeholder ecosystem covers some areas, but key gaps exist 2. Stakeholders with limited resource, background and experience in offshore wind industry. Possible experience of energy or O&G. Delays expected 3. Parties accepting of the importance of engagement, but no support or engagement process 4. Very limited stakeholder industry groups covering a few areas
Foundation (1)	1. Stakeholders do not exist to support offshore wind area 2. No planned or established engagement process 3. No stakeholder industry groups

Appendix B: What is involved in offshore wind energy?

Offshore wind combines decades of wind turbine development with expertise from other maritime industries. Its development is driven by major energy companies and dynamic local players, supported by a diverse supply chain.

Offshore wind has been a huge technical challenge. An offshore wind farm is not simply an onshore wind farm moved to the sea. It has spurred new turbine technology, novel foundation and developed new solutions to transmission challenges. It has led to major investments in new technology across the supply chain, giant specialist vessels and manufacturing facilities.

The success has been driven by developers and suppliers that have seen a business opportunity in a new industry.

An offshore wind farm project has four phases:

1. **Development**
2. **Construction**
3. **Operation**
4. **Decommissioning**

How is it developed?

Before an offshore wind farm is built, a developer must gain the rights to the site, secure the relevant permits, agree a grid connection, design the wind farm, undertake procurement and secure a form of offtake agreement. Once in place, the developer will reach a final investment decision.

Experience to date is that the development phase can take six or more years.

It is difficult to shorten this period for several reasons. It often needs two years of data to assess the environment impacts of the project and, with the number of stakeholders involved, permitting bodies can take two years to make an informed decision.

Offshore wind farms are complex, and the final design of the foundations and transmission system is only possible after a turbine model has been selected. Only once the transmission design is finalised and a final investment decision reached can the construction of the offshore substation begin. This is often on the critical path.

Often, local grid reinforcement is needed, and grid connection can become on the critical path.

For new markets, the process can take longer while organisations train staff and become more efficient. Over time, however, the process is expected to accelerate as all parties get more experienced.

A developer may award only two or three large contracts or opt for up to 12 smaller contracts. The choice depends on how the developer wishes to manage project risks and the resources it has available.

At all stages of the wind farm's life, safety is a priority.

Source: Ørsted

How is it operated?

The operation and maintenance (O&M) of a wind farm may be shore-based or offshore-based. If a wind farm is within about 40 nautical miles from port, it usually involves technicians 'commuting' daily to the wind farm using crew transfer vessels (CTVs). The O&M base is generally at the nearest suitable port and has offices, workshops, storage and vessel berths.

For distances greater than 40 nautical miles, it generally makes sense to use a service operation vessel (SOV), with accommodation for up to 60 technicians along with workshops, spare parts and consumables. Such a vessel may stay offshore for two weeks at a time. An SOV wind farm still has a shore base, which services as headquarters for the project and facilities to service the SOV as it comes into port.

O&M is split into planned and unplanned activity and a balance is struck between reducing expenditure and maximising the energy yield of the wind farm. Offshore turbines have been designed to be increasingly reliable and easy to maintain.

Planned activity consists of day-to-day inspections of the turbines as well as periodic exchange of worn parts and inspection campaigns of foundations and cables.

Unplanned activity can be in response to minor faults, handled by the wind farm's dedicated workforce and major repairs typically require specialist workers and vessels. Use of condition monitoring result in wind farm owners anticipating failures, so can take corrective action.

Offshore wind farms are designed for a life of 25 years and, in many cases, owners plan for the wind farm to continue operation beyond this. If the wind farm is no longer economic, the owner will decommission the wind farm. As much as possible is re-used or recycled, meeting environmental obligations defined before the wind farm was constructed.

The owner may choose to 'repower' the wind farm with newer turbines but in this case, little of the original infrastructure is suitable for re-use.

Source: Jan Arne Wold-Woldcam-Statoil

How is it built?

Construction of an offshore wind farm involves many complex tasks, undertaken many times over large areas. This poses risks because the impact of a single problem is magnified many times, but also it also means the industry can learn quickly. Offshore wind farms are mostly now built on time and budget.

New markets can benefit from this learning by partnering local companies with experienced industry contractors.

Conditions offshore are challenging, and weather plays a critical role in how the wind farm is installed. There has been significant investment in vessels and equipment to minimise delays due to weather.

Wind farm construction often starts with the transmission system because it is vital that once power is generated, it can be exported to the grid. For a fixed bottom wind farm, turbine foundations are installed, followed by the array cables (which link the turbines to each other and the offshore substation) and finally the turbines.

Final assembly of the turbines is generally offshore, with the tower, nacelle and each of the three blades added in turn. For floating wind farms, the turbines are likely to assembled directly on the foundations onshore, and towed to site.

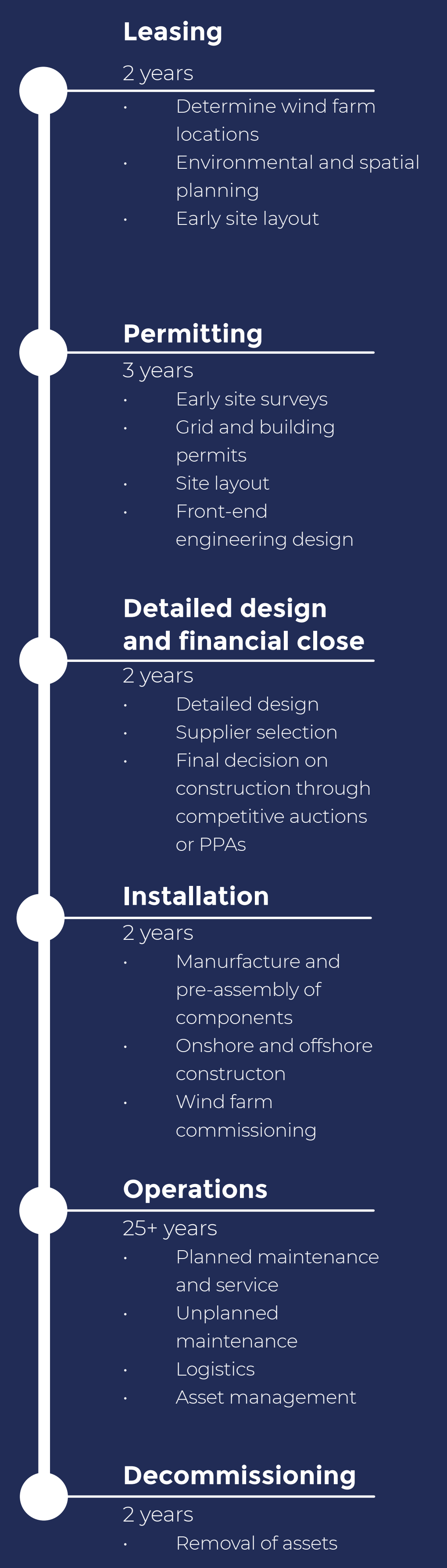
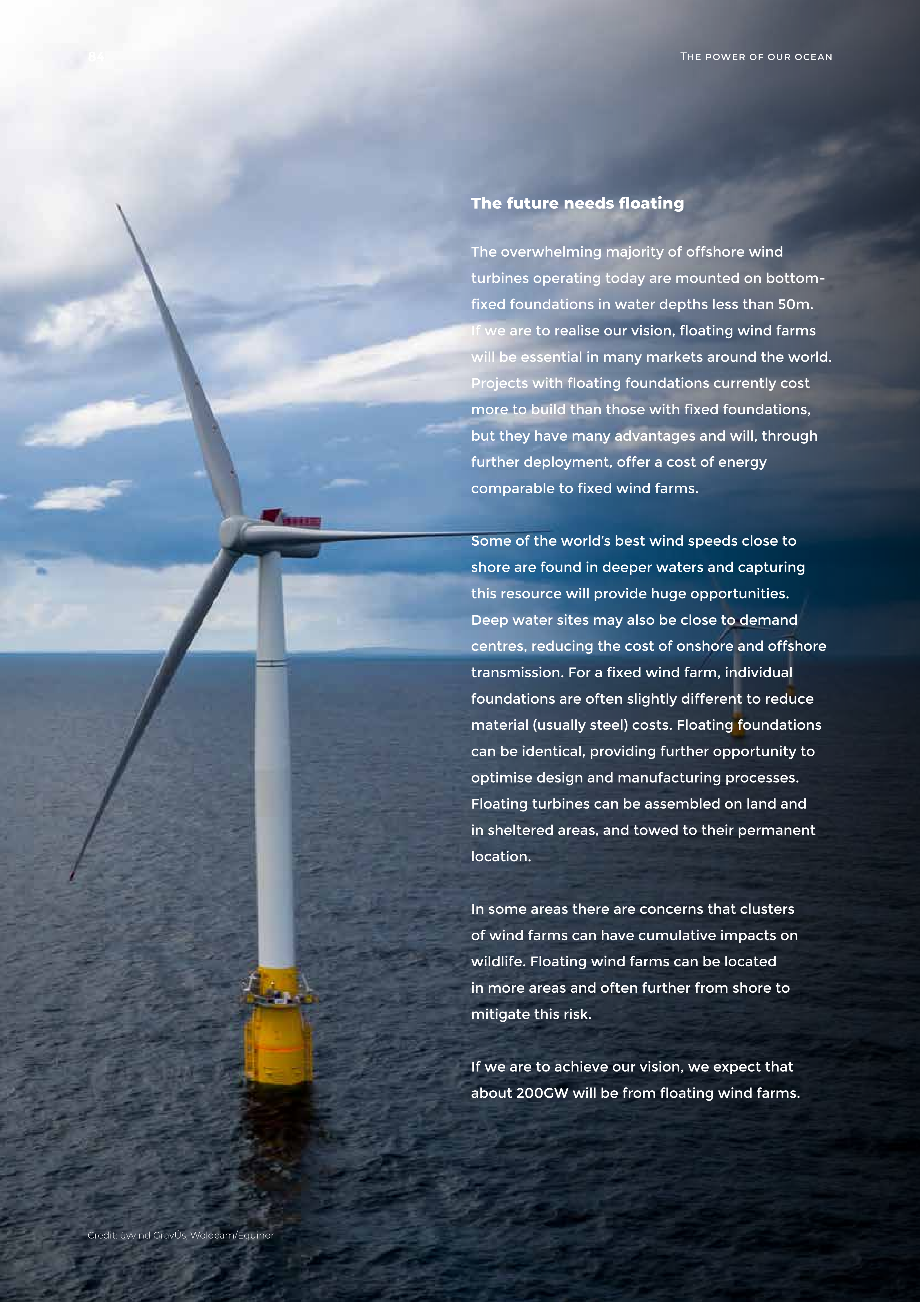


Figure 17 Phases of an offshore wind project



The future needs floating

The overwhelming majority of offshore wind turbines operating today are mounted on bottom-fixed foundations in water depths less than 50m. If we are to realise our vision, floating wind farms will be essential in many markets around the world. Projects with floating foundations currently cost more to build than those with fixed foundations, but they have many advantages and will, through further deployment, offer a cost of energy comparable to fixed wind farms.

Some of the world's best wind speeds close to shore are found in deeper waters and capturing this resource will provide huge opportunities. Deep water sites may also be close to demand centres, reducing the cost of onshore and offshore transmission. For a fixed wind farm, individual foundations are often slightly different to reduce material (usually steel) costs. Floating foundations can be identical, providing further opportunity to optimise design and manufacturing processes. Floating turbines can be assembled on land and in sheltered areas, and towed to their permanent location.

In some areas there are concerns that clusters of wind farms can have cumulative impacts on wildlife. Floating wind farms can be located in more areas and often further from shore to mitigate this risk.

If we are to achieve our vision, we expect that about 200GW will be from floating wind farms.

Credit: Øyvind GravÚs, Woldcam/Equinor

What is in an offshore wind farm?

The turbines

Offshore wind turbines use a three-bladed rotor connected to a nacelle that houses the equipment that translates the rotational energy of the rotor into electrical energy. Suppliers continue to developed new turbines that are larger, more reliable and easier to maintain. This reduces costs and maximises energy production.

There are significant benefits of larger turbines with bigger rotors. They reduce the number units that need to be installed and maintained and they have higher yields by capturing energy from winds at greater heights from sea level. In the 2020s, turbines will increase in capacity to at least 12MW and have rotors diameters greater than 200m. Technical developments are likely to lead to even larger turbines.

The foundations

Most offshore wind farms have been built in water depths less than 40m and the lowest cost foundation has been the tubular steel monopile, driven into the sea bed. The largest monopiles can have a mass of 1,500t. In deeper waters, options are to use lattice structures, known as jackets, or gravity bases that are mainly made of concrete. Jackets may use less steel than monopiles but are more complex to fabricate and install. Gravity bases have not been used widely but they may become attractive in some markets.

In water depths greater than 60m, it becomes more economical to use floating foundations. The floating market is rapidly developing, but large-scale projects have not yet been installed. Floating technology is essential to realise our vision.

Electrical system

Large-scale offshore wind farms need a substation to transform voltages and reduce transmission losses. Most offshore wind farms have used AC transmission but wind farms greater than about 120km from their onshore grid connection generally use DC transmission. DC transmission requires converter modules at the offshore and onshore substations. It costs more than AC to build but is an economic solution if the wind farm has high wind speeds.

Cables

Subsea cables are copper or aluminium and are protected by insulation and armouring. They mostly are buried in the sea bed to reduce the risk of damage.

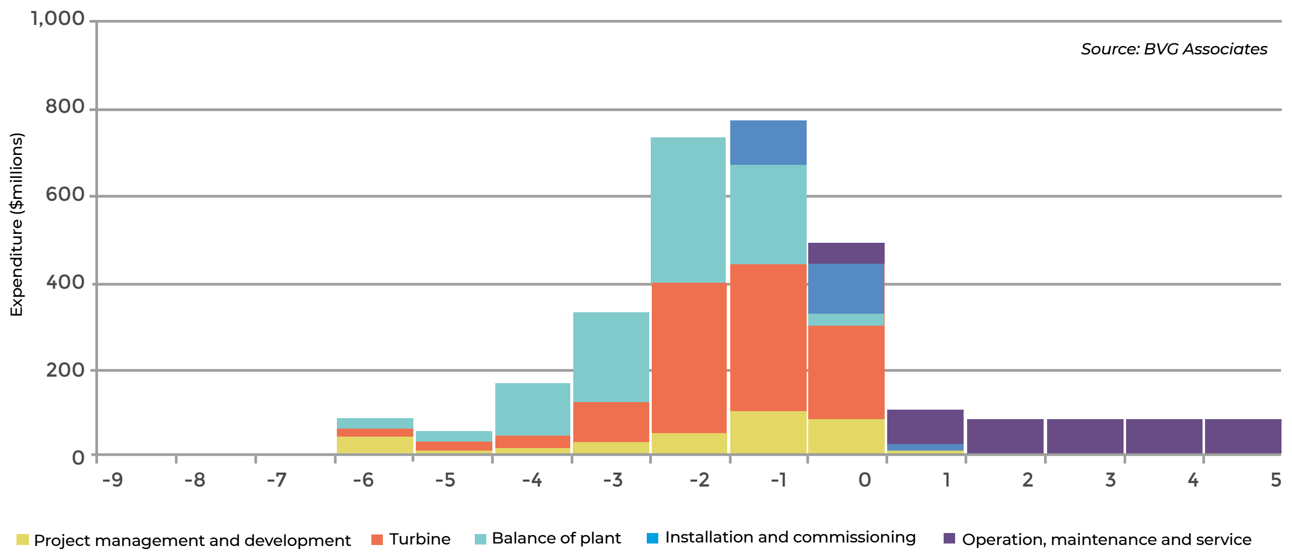


Figure 18 Capital spend profile of an offshore wind farm.

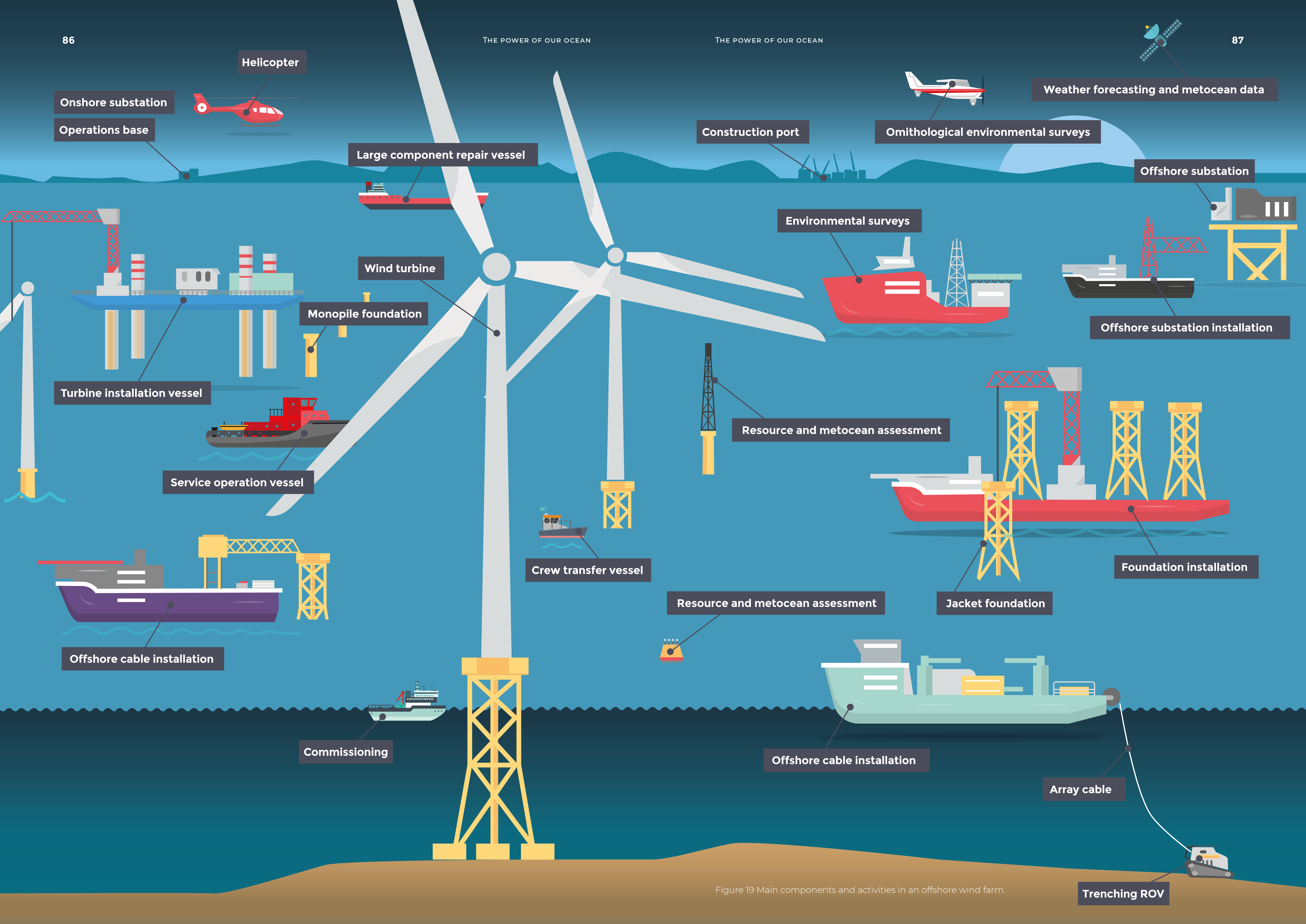


Figure 19 Main components and activities in an offshore wind farm.

Appendix C Glossary

Term	Definition
Asset management	Management of the operation, maintenance and upgrade of power generating plants, supported by engineering and economical practices.
Blue Economy	Sustainable economic development of ocean resources.
Developer	A company who initiates an offshore wind project, managing preliminary design stages, permitting and planning. Developers then either sell off the project to larger utilities or carry it through to commissioning and operation.
Direct electrification	Direct replacement of existing energy source with electricity.
Environmental impact assessment (EIA)	Assessment of the potential impact of the proposed development on the physical, biological and human environment during construction, operation and decommissioning.
Feed-in tariff	Fixed electricity prices paid to renewable generators, guaranteed for a set period of time.
Generator	Electrical production plant connected to the high voltage grid.
Indirect electrification	Electricity is used as an input for an industrial process or for the production of a synthetic fuel.
Levelised cost of energy (LCOE)	A measure of the cost of electricity production. It is defined as the revenue required (from whatever source) to earn a rate of return on investment equal to the weighted average cost of capital (WACC) over the life of the wind farm. Tax and inflation are not modelled.
Marine spatial planning (MSP)	Efficient accommodation of different users of the seas and protection of sensitive ecosystems.
Organisation for Economic Co-operation and Development (OECD)	Intergovernmental economic organisation with 37 member countries, to stimulate economic progress and world trade.
Power Purchase Agreement (PPA)	Long term fixed price contract between electricity generator (seller) and purchasing company (buyer).

Term	Definition
High Level Panel for a Sustainable Ocean Economy (Ocean Panel)	A unique initiative of 14 serving world leaders building momentum toward a sustainable ocean economy, where effective protection, sustainable production and equitable prosperity go hand-in-hand.
Transmission system operator	Entity responsible for the transmission of power from generators via the high voltage electrical grid.
WindEurope	Voice of the wind industry, actively promoting wind power in Europe and worldwide.

Abbreviations	Definition
AC	Alternating current
APAC	Asia-Pacific region
CO2	Carbon dioxide
CTV	Crew transfer vessel
DC	Direct current
EIA	Environmental impact assessment
GHG	Greenhouse gases
GW & GWh	Gigawatts and gigawatt hours, There are 1,000MW in a GW
GWEC	Global Wind Energy Council
HVAC	High voltage alternative current
HVDC	High voltage direct current
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
LCOE	Levelised cost of energy

Abbreviations	Definition
MSP	Marine spatial planning
MW & MWh	Megawatts and megawatt hours
NOx	Nitrogen oxides
O&G	Oil & gas
O&M	Operations and maintenance
OECD	Organisation for Economic Co-operation and Development
PINS	Planning Inspectorate (UK body responsible for assessing permit applications)
SO_2	Sulphur dioxide
SOV	Service operation vessel
TW and TWh	Terawatts and terawatt hour, There are 1,000GW in a Terawatt

Source: GE Renewable Energy

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