Key Factors for Successful Development of Offshore Wind in Emerging Markets

ESMAP

WORLD BANK GROUP
THE WORLD BANK IBRD • IDA
IFC International Finance Corporation

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Through the WBG, ESMAP works to accelerate the energy transition required to achieve Sustainable Development Goal 7 (SDG7) to ensure access to affordable, reliable, sustainable, and modern energy for all. It helps to shape WBG strategies and programs to achieve the WBG Climate Change Action Plan targets.

FOREWORD | WORLD BANK

Offshore wind is poised to play a significant role in global efforts to reduce greenhouse gas emissions. With its abundant resource, large scale and rapidly decreasing costs, offshore wind can make an important contribution in the global transition to net-zero emissions. Recent analysis suggests that up to 2,000 GW of offshore wind capacity will be needed by 2050 if we are to keep global temperature increases below 1.5 degrees C. At present there is no offshore wind capacity in emerging markets outside of China. This will need to change if these ambitious but achievable targets are to be met. However, the long development timescales for offshore wind mean that efforts need to start now to ensure delivery of new capacity.

The recent maturing and large-scale roll out of offshore wind, particularly in Northern Europe, has led to cost reductions of more than 70%. Furthermore, offshore wind has shown an ability to generate economic benefits through industrial development and the creation of long-term, skilled jobs; illustrating how communities can prosper and flourish after transitioning from hydrocarbon-based to clean energy economies.

Offshore wind offers many developing countries with an attractive option for large-scale, clean electricity generation, as identified in the World Bank Group's latest Climate Change Action Plan. To aid in this global roll-out, the joint ESMAP-IFC Offshore Wind Development Program was established in 2019 with the aim of accelerating the uptake of offshore wind in emerging markets. Analysis by the Program has identified vast technical potential in low- and middle-income countries. Despite this attractive opportunity, few emerging markets have established targets and policies for offshore wind. Here it must be recognized that development of offshore wind is not easy; it is complex and requires strategic government vision and commitment.

Experiences from established markets, as highlighted in this report, have shown that governments need to be proactive to successfully deliver affordable, large-scale offshore wind capacity and reap the socio-economic benefits that this industry can bring. Offshore wind is very different to onshore wind and solar, and without strong government backing and coordination, it is unlikely to achieve its potential. The sheer scale of capital required to deliver offshore wind typically requires some level of international investment alongside local financiers. To unlock lower cost international financing, it is essential that projects meet international lenders' requirements, especially for environmental and social sustainability and the bankability of offtake agreements.

Each country also has its own local context and characteristics. This report therefore does not offer a single, recommended path to delivering offshore wind, but rather identifies the key factors for success. These factors are intended to help guide governments in establishing policies, processes, and regulatory frameworks that best suit their country but also maximize the chance of delivering a successful new sector. The numerous lessons learnt, case studies, and references provided in this report help to share this industry's experiences over the past thirty years and to aid governments to make evidence-based decisions.

It is also important to recognize the different challenges faced when delivering large infrastructure like offshore wind in an emerging market. These challenges are well understood by the World Bank Group, through its long track record in supporting and financing energy and infrastructure projects across the globe. The World Bank is committed to supporting governments to work through these challenges and put in place the strategies, policies, and frameworks needed to establish a new sector, and also stands ready to provide financing for the deployment of offshore wind in these emerging markets.

Demetrios Papathanasiou,
Global Director for the World Bank's Energy and Extractives Global Practice

FOREWORD | GWEC

Offshore wind faces an unprecedented opportunity over the coming decade and beyond. It is having a breakthrough moment, as governments and investors around the world recognise the unique possibilities of the technology. Offshore wind is one of the few technologies that can provide clean power at a large-scale; generate with high capacity factors and availability; be cost-competitive with fossil fuelled generation; and provide a strong stimulus for investment, offering considerable opportunities for economies and communities.

Recent landmark reports by both the International Energy Agency (IEA), and the International Renewable Energy Agency (IRENA) establish a strong, global role for offshore wind in transitioning to net zero by 2050. Both foresee offshore wind providing at least 2,000 GW of capacity by 2050, compared to just over 35GW at the end of 2020 (see GWEC's Global Offshore Wind Report 2020). This implies a heady rate of growth, and the rapid adoption of the technology by governments, particularly in fast-growing developing nations. Hence the importance of the World Bank's efforts to take offshore wind to these emerging markets – which GWEC has strongly supported. And hence the importance of this report.

As well as being a climate imperative, there is much to be gained for economies and communities, as they struggle to emerge from the COVID-19 pandemic, stimulate economic growth and renew their infrastructure. Offshore wind can play a key role in helping governments deal with the challenges of creating a 'just' energy transition by reskilling and repurposing workers involved in the sunset industries of fossil fuel extraction, distribution and generation.

Offshore wind can potentially act as a strong catalyst for investment in regions such as South East Asia, Latin America, and Africa, given the strong appetite to invest in the technology from multilateral institutions such as the World Bank, development financial institutions such as IFC, commercial banks, pension funds and institutional investors. But while there is a strong availability of capital to be tapped, it's important to emphasise the critical role that governments will need to play to establish the policy, the regulatory frameworks, and supportive infrastructure needed to establish successful offshore wind sectors.

Very large investments are also necessary in supply chain capacity, grid and port infrastructure, as well as workforce development over a sustained period. Lead times can be relatively long, so the need for clarity and a long-term vision through clear energy policy and targets is of fundamental importance, as is the need for certainty and avoiding sudden changes to market frameworks.

And last of all, and perhaps most importantly, the accelerated deployment of offshore wind will require a heightened degree of cooperation between countries. The experience around the North Sea of strong inter-governmental and inter-agency coordination on marine spatial planning and the creation of a multinational supply chain was fundamental to the creation of the European offshore wind sector. It is GWEC's view that the creation of similar regional ecosystems will be of equal importance to the emergence of offshore wind sectors in Asia, the Americas and elsewhere.

All this may seem to constitute quite a tall order. However, the best practice examples which this report identifies show that, with the right amount of commitment and determination, the world is capable of building a new industry that can completely change the traditional order.

None of this will happen on its own of course. GWEC is working with the World Bank to provide a wide-ranging programme of knowledge transfer and technical assistance to help governments, countries and regions quickly realise their offshore wind potential. By providing a comprehensive account of the key factors for success in offshore wind, this report will play an important role in this effort in the months and years to come.

Ben Backwell
CEO, Global Wind Energy Council (GWEC)

EXECUTIVE SUMMARY

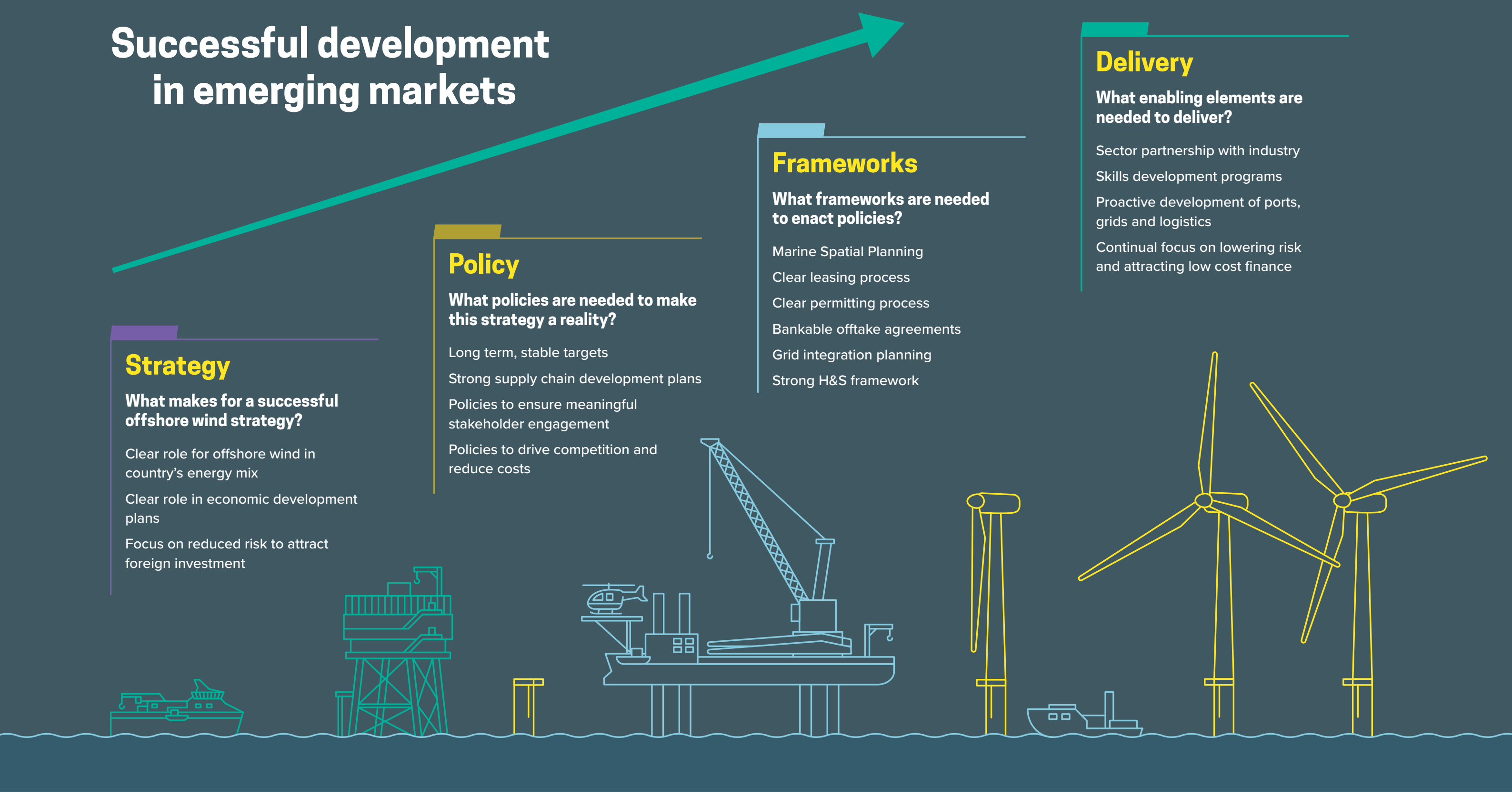
Offshore wind holds tremendous promise for many emerging markets as a large-scale, clean, reliable form of new electricity generation with the potential to stimulate valuable economic benefits. However, developing a new offshore wind sector in an emerging market is no easy task. Decision makers must strike a careful balance as they consider a range of technical, political, environmental and social challenges. Offshore wind projects combine the scale of large hydro and the complexity of offshore hydrocarbon extraction, making them entirely different from onshore wind or solar. Government support and proactivity is, therefore, essential to develop a successful new sector and deliver the high rewards that offshore wind can bring.

Fortunately, there is a great deal of knowledge and experience to be gained from countries that have successfully established their offshore wind sectors. Each has had their successes and failures and offer important lessons to aid policymakers in emerging markets, make informed decisions. These decisions also need to suit the particular characteristics and needs of that country so applying lessons learned is not simply a cut-and-paste exercise.

This report distils experiences from established offshore wind markets into key success factors to help emerging markets build successful offshore wind sectors that follow international good practices while reflecting the unique contexts of each country. The key factors described here are, therefore, directional rather than prescriptive. Although this report's primary audience is the government officials and stakeholders in low- and middle-income countries, many of the issues and key factors are equally applicable to other countries. The report also recognizes that different stakeholders have different roles to play in a sector's development; from politicians setting out strategies to port owners planning new facilities. As such, the report intends to support each audience and their particular concerns while also providing an understanding of how their parts are woven into the big-picture.

An offshore wind market can be characterized as four interdependent pillars, namely: **Strategy, Policy, Frameworks** and **Delivery.**

Strategy refers to a country's long-term planning to develop offshore wind as part of the future energy mix; this is usually established by politicians, decision makers, and energy planners who understand the role that offshore wind can play in the country's economic and social fabric. **Policy** refers to the underlying political ambitions, laws, and agreements that will turn the strategy into reality; these are usually implemented by lawmakers and bureaucrats. **Frameworks** are the mechanisms through which the policies are enacted; these are usually implemented by government agencies and utilities. Finally, **Delivery** refers to the enabling environment required to deliver on-the-ground results; these are implemented by governments in partnership with industry, civil society and other stakeholders.



Experience from established markets suggests that each of these pillars must be tightly interconnected with each other and exhibit the following Key Factors:

- A successful **Strategy** should establish a clear national role for offshore wind from both an energy and socio-economic perspective. When deployed at large-scale offshore has wide-ranging impacts in terms of job creation, supply chain development, emission reductions, energy independence, electricity prices, and foreign direct investment. Sometimes these impacts are complementary and sometimes they are at odds - for example, when prioritization of local supply chain development leads to higher electricity costs. For this reason, and because of the long timescales needed to develop offshore wind, stakeholders need to understand the country's motivation and drive to pursue offshore wind before they invest the time, money, and resources. The UK and Denmark, for example, clearly prioritize and articulate the reasons for offshore wind being part of their long-term energy strategies. These strategic reasons lay the foundation for policies.
- A successful **Policy** environment should establish realistic, long-term targets, and a broad array of actions addressing energy planning, supply chain development, stakeholder engagement and long-term cost reduction. Owing to its scale and complexity, policies need to balance the different (and sometimes competing) interests of governments (e.g. economic development, job creation), industry (e.g. profitability, risk management), civil society (e.g. environmental and social protection, social benefits) and ratepayers (competitively-priced electricity). The key to success is a cornerstone policy or legislation that commits the country to a long-term offshore wind vision with predictable target milestones over a period of at least ten years. This policy should outline the procurement method and approach to long-term cost reduction through increased competition. This should be accompanied by complementary policies that: a) promote workforce development including transition from other sectors, b) incentivize offshore wind supply chain activities, c) establish marine spatial planning activities to balance conflicting priorities, d) establish rules for stakeholder engagement, particularly around fisheries and coastal communities, e) establish environmental and social impact review processes that follow international standards, and; f) facilitate development of associated infrastructure such as transmission grids and ports. Several countries provide examples to follow in strong offshore wind policy development, including the Netherlands, Poland, and Taiwan.

- A set of **Frameworks** should be developed to provide the processes and rules that turn the policies into reality. These should be implemented through agencies with clear roles, well-defined mandates, and sufficiently resourced staff. Success in established offshore wind markets has resulted from strong frameworks in seven key areas: marine spatial planning (MSP), leasing, permitting, offtake and revenue, export systems and grid connection, health & safety, and standards & certification. In each case, there are several key factors to success. First, each implementing agency should engage with relevant stakeholders and adapt existing frameworks and processes such that they follow international good practice and are fit-for-purpose (recognizing that, what works for onshore wind and solar may not work for offshore wind). Second, the agencies should closely coordinate their approach and ensure a smooth, client-focused interface; in this regard streamlined processes should be created. Third, each process must be transparent, proportionate, timely and flexible, with clear risk allocation and defined milestones that provide long-term certainty. Fourth, the frameworks should focus on minimizing risks for all parties, including bankable offtake agreements, and clear rules around grid access and curtailment. Lastly, the frameworks and processes must place health and safety as absolute priorities at each step, seeking to instill a work culture in the offshore wind sector where every worker returns home safely.
- Successful **Delivery** of offshore wind should focus on flexibility, continuous learning and improvement, and ongoing consultation with stakeholders. To be successful, new markets need to deliver on the day-to-day and year-to-year implementation of the policies and frameworks, with a focus on four areas: supply chain, ports, transmission grid, and financing. In each case, experience in mature markets point to the following success factors: First, government-industry-stakeholder partnerships are an effective mechanism for providing feedback and adjusting delivery as needed; this is particularly important in the areas of supply chain and transmission which have frequently been pinch points. Second, a focus on flexibility and learning-by-doing helps both governments and stakeholders adapt to changing conditions. Third, a consistent focus on bankability is critical to attracting financing and bringing down costs of both offshore wind projects and the manufacturing, ports, and logistics operations needed to support them. Lastly, maintaining a long-term view on what will be needed to accommodate future offshore wind deployment; this is critical for associated infrastructure which requires a long lead time such as transmission and ports.

Taken together, these key factors will assist emerging markets in accelerating the time it takes to develop a successful offshore wind sector. The World Bank Group (WBG) Offshore Wind Development Program stands ready to work with governments, industry, civil society, and stakeholders as they work towards this goal.

INTRODUCTION

Purpose of the Report

The World Bank Group's (WBG) Offshore Wind Development Program is jointly led by the Energy Sector Management Assistance Program (ESMAP) and the International Finance Corporation (IFC). It intends to accelerate the deployment of offshore wind in emerging markets, by offering a range of technical and financial support. Mapping and analysis under this program estimates [1] there is over 16,000 GW of offshore wind technical potential resource in developing countries, highlighting a vast, untapped opportunity. The Program is undertaking a series of country roadmap studies to aid governments in developing countries assess their offshore wind resources further and to understand the role that offshore wind could play in their transition to a net-zero economy.

This report complements the Program's country specific work and is intended to help policy makers and government officials in the WBG client countries answer the questions *"should we develop offshore wind?"* and *"what do we need to do to establish and grow a successful offshore wind market?"*

To answer these questions, this report outlines the key success factors for each of the main "pillars" that are required to deliver an offshore wind industry. These key success factors are supported by numerous references, good practices, lessons learned, and case studies, which should help governments and civil servants to make informed, evidence-based decisions.

While emerging markets can benefit from decades of experience from the evolution of established offshore wind markets, creating new industries in low- and middle-income countries will present new challenges to overcome. Not all industry best practices will be appropriate or achievable in emerging markets. It is therefore important for governments in emerging markets to understand the key success factors presented in this report and use them as a guide to establish a new offshore wind sector within the local context.

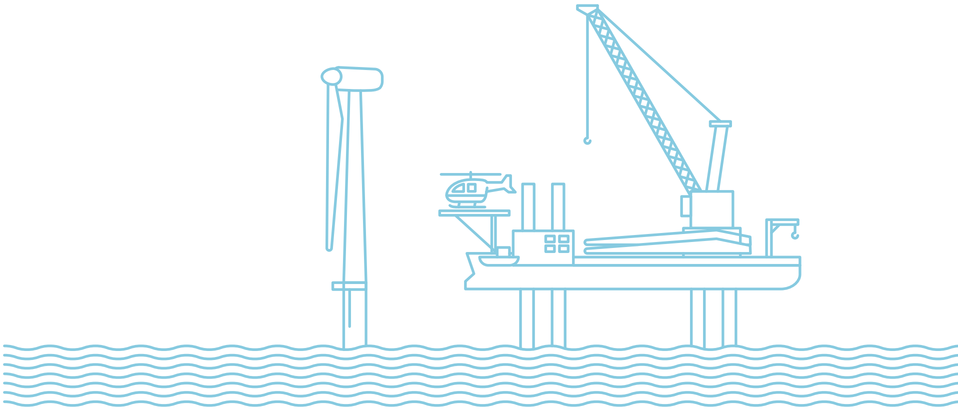
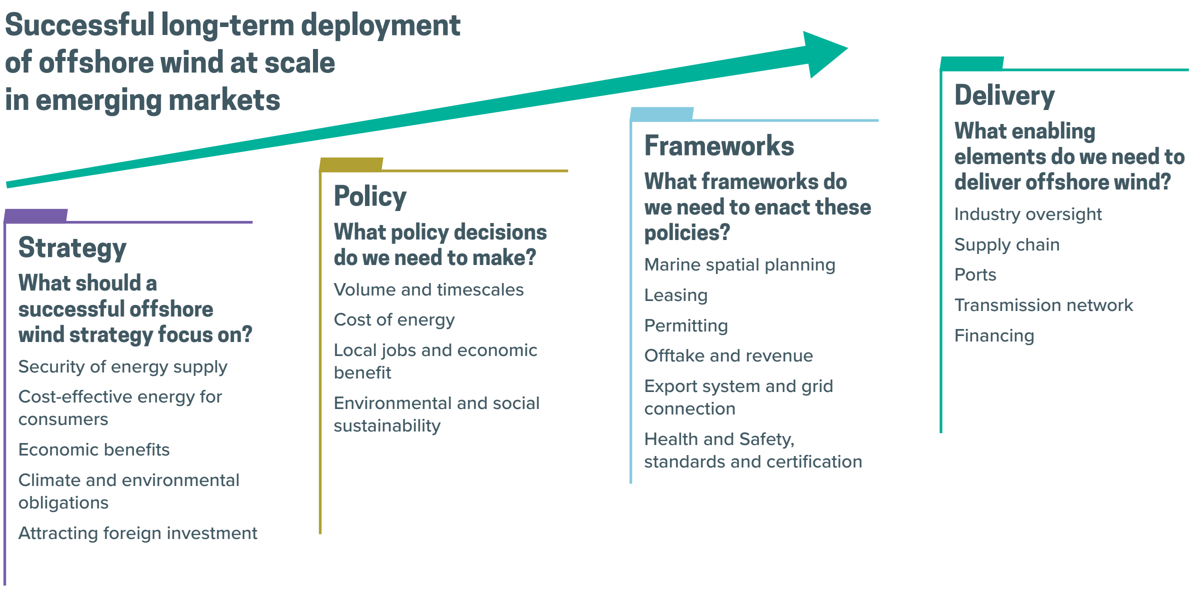


FIGURE IN.1: Strategy, policy, framework, and delivery: the four key pillars for successful development of offshore wind



Four Pillars of an Offshore Wind Market

This report presents four pillars supporting a market, each with multiple elements and key success factors. In practice, however, these pillars are linked and there is crossover between them. The elements comprising each pillar help policy makers to answer important, strategic questions such as:

1. **Strategy:** What does a successful offshore wind strategy look like?
2. **Policy:** What policies should we start with?
3. **Frameworks:** What systems do we need to enact these policies?
4. **Delivery:** What enabling elements do we need to deliver cost-effective offshore wind?

Each of these four pillars must act together to establish and grow an offshore wind industry. It is essential that all elements within these pillars are in place and fit for purpose because, without each of them in place, the new industry may not be successful.

Reader Navigation Guide

The four pillars have their own, dedicated chapters in this report. Key success factors are presented as summary conclusions for each section. The chapters and their sections are set out here.

Chapter 1 Strategy

Determines the strategic relevance of offshore wind as part of a country's transition to a climate-neutral economy. This section considers the following:

- Important issues to understand when looking at offshore wind as part of an energy strategy.
- Other macro, strategic issues (such as the economy and climate) that can influence the inclusion of offshore wind in a country's energy strategy.

Chapter 2 Policy

Establishes a long-term vision for offshore wind (based on offshore wind's role in the energy strategy), and provides policies that gives market confidence and government priorities to inform the creation of frameworks and delivery support initiatives. This section considers:

- Volume and timescales. Providing confidence to investors through clarity on targets and government aspirations.
- Cost of energy from offshore wind. Route to achieving low-cost energy for consumers.
- Local jobs and economic benefits. Securing economic benefits while supporting industry growth.
- Environmental and social sustainability. Avoiding and minimizing impacts on the environment and biodiversity, other sea users, and local communities, while capitalizing on the environmental and social benefits of offshore wind.

Chapter 3 Frameworks[1]

Establishing frameworks, based on policy statements, that provide a clear route for offshore wind projects to be constructed. This section considers:

- Organizing frameworks. Ensuring coordination for an efficient and cost-effective route for projects.
- Marine spatial planning.[2] Enabling larger volumes of offshore wind to be sited in the most environmentally, socially, and commercially appropriate locations.
- Leasing.[3] Providing project developers exclusive rights to survey sites on which to then construct and operate offshore wind projects.
- Permitting.[4] Providing project developers permission to construct and operate offshore wind projects that are deemed to be acceptable.
- Revenue[5] and offtake. Lowering revenue risk to enable investment decisions in offshore wind projects and provide certainty through long-term bankable offtake agreements.
- Export system[6] and grid connection.[7] Enabling timely connection to the transmission network.
- Health and safety. Minimizing workplace risks and protecting onshore and offshore workers.
- Standards and certification. Managing risk through standardization and certification to international standards.

1 Frameworks mean regulations, processes, and guidelines to give structure to different key aspects of the delivery of offshore wind.

2 Marine spatial planning is a process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas.

3 Leasing means the exclusive rights to develop an offshore wind farm (and associated infrastructure) at a given location.

4 Permitting means the environmental and all other permissions to install and operate an offshore wind project.

5 Revenue support means any public mechanism that supports through-life revenue to enable the decision to invest in an offshore wind project.

6 Export system means the equipment and assets required to connect offshore wind generating assets to the transmission network.

7 Grid connection means the approach taken to secure export capacity for an offshore wind farm, which subsequently connects to the wider electricity transmission network.

Chapter 4 Delivery

Collaborates to ensure ongoing delivery of policy objectives as the market develops.

- Supply chain.[8] Enabling local jobs and value creation through the supply of components and services to offshore wind projects.
- Ports. Unlocking investments to support efficient project delivery.
- Transmission network.[9] Ensuring the transmission network is developed to be ready for offshore wind and other generation capacity.
- Financing. Addressing risk to enable sufficient volume of low-cost finance to support offshore wind.

Chapter 5 Next Steps

Sets out key sources of additional support, future industry developments, and next steps for government.

Case Studies, References, and Further Reading

The text is supported by case studies and references throughout. Many case studies are from established markets because this is where experience has been gathered, but they have been chosen carefully to be of relevance to emerging markets in the World Bank Group (WBG) client countries.

Prices stated in other currencies are also stated in equivalent US dollar values, using representative exchange rates at the time of writing.

Appendix A: Recommended Further Reading provides a list of recommended further readings for each section, along with guidance about the relevance of each item listed. The full list of reference sources is provided in Appendix B: References.

Appendix C: Glossary provides a list of acronyms and terminology used in this report.

8 Supply chain means the network of organizations that supply parts or services to the offshore wind sector.

9 Transmission network means the wider high voltage electricity network.

1 STRATEGY

1.1 Introduction

Any country interested in exploiting its offshore wind energy resources needs to answer the fundamental question *"should we develop offshore wind?"*

The first step in answering this question is to **understand the technical feasibility of offshore wind** in the waters over which the country has internationally recognized rights. This assessment would consider the wind resources and offshore characteristics to determine whether offshore wind could be a technically viable option and to give an initial view on potential costs. This report assumes that readers have already established that offshore wind is a possible option. Further information on this subject can be found in related studies for India [17] and Vietnam [2], or by speaking with the World Bank Group representatives for advice.

The next step is to consider how offshore wind could fit into the country's long-term energy strategy. In considering this, policy makers need to ask macro-level, strategic questions such as:

- Can offshore wind improve the country's energy security?
- What contribution can it make to meet the country's future energy demands?
- Is there potential for some generation to be exported to other markets?
- Does its seasonal and diurnal output variation complement other types of electricity generation?
- Can it be affordable and generate cost-effective energy for consumers?
- What economic benefits can it create, in the form of jobs and supply chain development?
- What contribution can it make to help meet climate and environmental obligations?
- How much foreign direct investment can it bring?

Every country will have different strategic drivers and issues, so it is important to realize that the reasons to develop offshore wind will be different from country to country. This chapter explores some of the common considerations when answering these questions and provides evidence to help support these decisions.

1.2 Offshore Wind as Part of an Energy Strategy

Offshore wind should be considered as part of a long-term energy strategy (or integrated resource plan)[10] alongside other forms of energy production.

Security of Energy Supply

Offshore wind can help meet increasing electricity demand in emerging economies and reduce reliance on imported fuels. Imported fuels such as natural gas or crude oil for electricity generation can be subject to significant price fluctuations. Offshore wind can help a country achieve the security of its energy supply and energy independence.[11] Examples of energy strategies incorporating offshore wind can be seen in the UK (Case Study 2.2) [3] and in Denmark [4].

Offshore wind projects provide large-scale electricity generation, with higher capacity factors[12] than onshore wind and solar projects. Projects exceeding 1 GW, with capacity factors of greater than 50 percent, are in development in established markets. High offshore wind power plant availability[13] (over 95 percent) and more consistent and higher wind speeds offshore[14] mean that a typical offshore wind turbine can generate electricity for more than 8,000 hours per year (around 340 days) in areas of good wind resource [5]. This can provide predictable, lower variability generated output, which is beneficial for system balancing.

As the proportion of renewable generating capacity increases on a system, the need to consider short-term energy balancing increases. This is due to the variable nature of wind and solar resources, which needs to be managed as part of the wider demand, supply, and storage system design.

Important considerations include:

- Reviewing the flexibility of the existing generation mix and the role of dispatchable[15] technologies.
- Utilizing new technologies to manage supply and demand, including energy efficiency measures, demand-side response, and storage technologies.
- Creating value for sustainable generators that can keep the grid balanced and stabilized.
- Where possible, utilizing international interconnectors between countries. This is because it is easier to balance supply and demand in larger systems.[16] With interconnectors it is possible to transport renewably generated energy from areas with good available resources to areas with low resources.

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10 An integrated resource plan is a utility planning process that considers both supply- and demand-side options to fulfil predicted future energy demands.

11 Energy independence means when a country can meet its energy demand with resources from its own country. It is acknowledged that full independence is not always right for a country. Interconnection between nearby countries will also be an important part of most energy supplies.

12 Capacity factor is the ratio of actual electricity produced over a period to the maximum possible electrical output over that period. Capacity factors of 40–50 percent are common in offshore wind and are mainly dependent on the wind resource, site optimization, and operation and maintenance (O&M) approach.

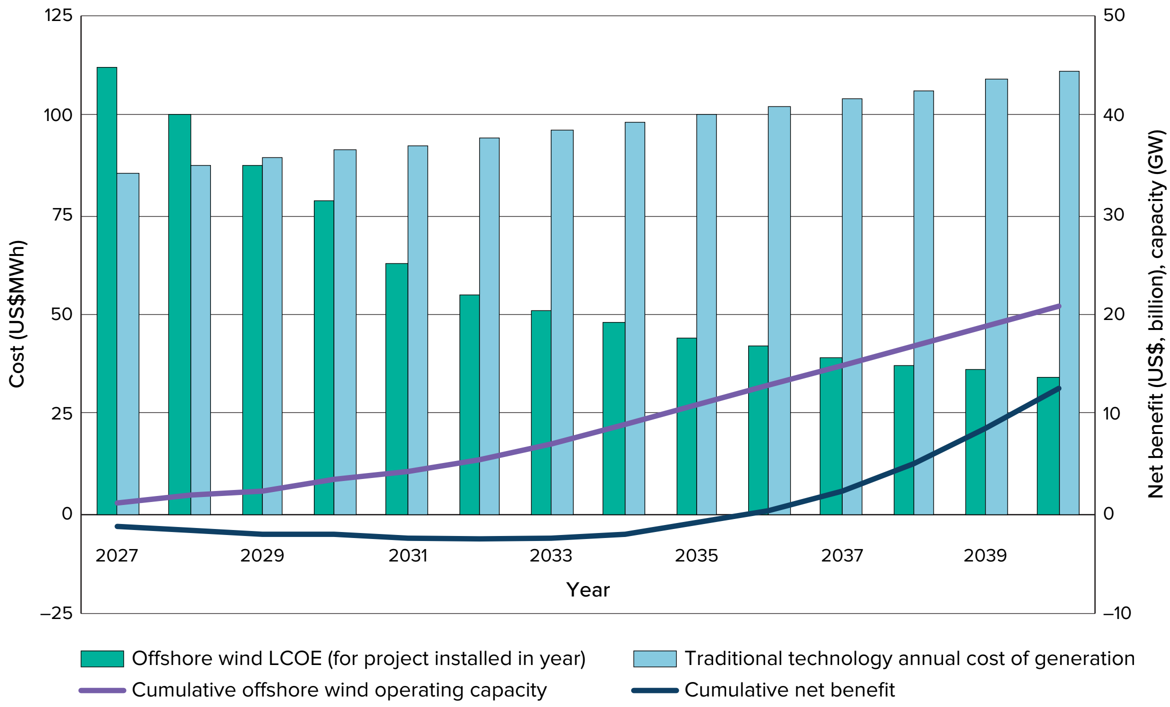
13 Plant availability is the proportion of time that the offshore wind project is fault-free, hence “available” to generate (even though wind speed may not be suitable for generation).

14 Offshore winds are generally more consistent in terms of wind speed and direction than onshore.

15 Dispatchable refers to having an output that can be controlled upward, downward, or both.

16 Both the European Commission [327] and the wind industry [49] recognize the importance of increased international interconnection.

FIGURE 1.1: LCOE and Cumulative Net Benefit of Offshore Wind in a High-Volume Emerging Market



Note: Adapted from [2].[17]

Cost-Effective Energy for Consumers

In emerging markets, the costs of early offshore wind projects may be higher than other energy sources; over time the costs will reduce as the market develops. In a least cost generation plan, early offshore wind projects will not necessarily come out favorably in the short term; however, this should not exclude offshore wind from an energy strategy due to the potential long-term economic benefits. In established markets, auctions are showing that new offshore wind farms are already delivering lower levelized cost of energy (LCOE)[18] than new-build nuclear and fossil fuel plants [6] [7]. The same trend will be available for emerging markets of sufficient scale and wind resources.

It is important therefore that governments plan their long-term energy strategy based on future costs and work to reduce costs of early projects as much as possible, while establishing a sustainable long-term market. Figure 1.1[19] uses data from the World Bank *Roadmap for Offshore Wind in Vietnam* [2]. It shows that in

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17 The blue bars show the annual average cost of energy for traditional technology operating in the given year, assumed to increase slowly over time due to fuel price inflation and other carbon abatement measures.
The purple line shows the cumulative installed capacity of offshore wind in Vietnam in this scenario.
The black line is the cumulative net cost of production from offshore wind minus what production would have cost from traditional technology, each year.

18 LCOE 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. In other words, it is the lifetime average cost for the energy produced, quoted in today's prices. LCOE is used to evaluate and compare the cost of electricity production from different technologies and at different locations. It is a good way to compare the cost of a unit of energy produced. LCOE does not consider costs relating to balancing supply and demand, transmission, and distribution to consumers. See section 2.3 for more discussion of LCOE.

19 The green bars show the LCOE for offshore wind installed in the given year, assumed constant for the 25-year life of the plant. The total cost of offshore wind production in any given year is made up of higher cost earlier projects and lower cost later projects, combined with capacity factors for each.

early years there is a net cost for production from offshore wind, peaking at a cumulative net cost of US$6 billion, but that by 2036, lower cost production from offshore wind has led to a break-even position. The cumulative benefit by 2040 is already US$25 billion, with further benefits every year as projects continue to deliver. A successful offshore wind industry will reduce the LCOE from offshore wind projects to be in line with the globally established markets quickly, thereby minimizing cumulative net costs.

Floating offshore wind in deeper water is likely to become cost competitive with offshore wind on fixed foundations in shallower water by the early to mid-2030s. The offshore wind market currently is dominated by fixed foundation projects (up to about 60 meters of water depth), but over the next 20 years this will change, opening up new markets with good wind resources close to population centers, but with deeper water. It is important for governments to progress opportunities for floating offshore wind early enough to not hold up future floating wind development. Turbines for floating projects will be the same as for fixed, but foundations, installation methods, and port requirements (see section 4.3) will be quite different.

Markets that have clear policy and robust frameworks to nurture an offshore wind industry can rapidly and significantly reduce the cost of energy. In Europe, the typical cost of energy from offshore wind in 2015 was in the range of US$150 to US$200/MWh. By 2019 this reduced to US$60/MWh in countries with established markets and good wind resources [7]. This already brings offshore wind costs below wholesale market prices, with further cost reduction anticipated as the technology and global supply chain further develop (see section 2.3 for further details on cost of energy). As conventional fossil fuel generation costs are expected to rise, offshore wind will become more cost competitive.

Onshore and offshore wind, hydro, and solar are the key renewable energy technologies that will support the move to a net zero carbon energy system. It is important to assess the potential contribution of each to help establish a cost-effective strategy. Local characteristics such as wind resource, water depths, and seabed conditions can influence how cost competitive offshore wind can be. Existing infrastructure such as ports and transmission networks, supply chains, and neighboring markets also influence the cost of early projects; however, these can be developed over time.

Local Jobs and Economic Benefits

Offshore wind generates economic benefits by creating jobs to support the manufacture, construction, and operation of projects. A localized supply chain can add value to an economy by providing a range of components and services that are required for an offshore wind project. It is estimated that 2.1 million days of work is created for a 500 MW offshore wind project over its life [7]. It is, therefore, important for governments to consider offshore wind's potential contributions to local economic and industrial strategies, in addition to its role in the energy strategy. See section 2.4 for a more detailed discussion of employment, including references to documents describing the types of jobs created during the development, construction, and operating phases of offshore wind projects.

Emerging markets with electricity generated by offshore wind can attract international companies that are seeking to decarbonize their supply chains. Global corporations are becoming more aware of climate change and are taking measures to reduce the impact of their supply chains. Companies such as Nike [8], Apple [9], Google [10], Heineken [11], and Amazon [12] have pledged commitments to net zero carbon emissions. Initiatives such as RE100 [13] and Science Based Targets Initiative (SBTI) [14] have successfully received pledges from companies such as TCI in Taiwan [15] and SK Hynix in South Korea [16]. One way that companies achieve carbon reductions is by directly purchasing electricity generated by renewable sources through Corporate Power Purchase Agreements (CPPAs)[20] with developers. This decarbonization of the supply chain creates economic opportunities for countries that have a supply of renewable energy.

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20 A CPPA is a power purchase contract between a project owner and a corporate end user of electricity. CPPAs have become popular for high users of electricity in consumer facing markets as a way to meet corporate social responsibility commitments around renewable energy use.

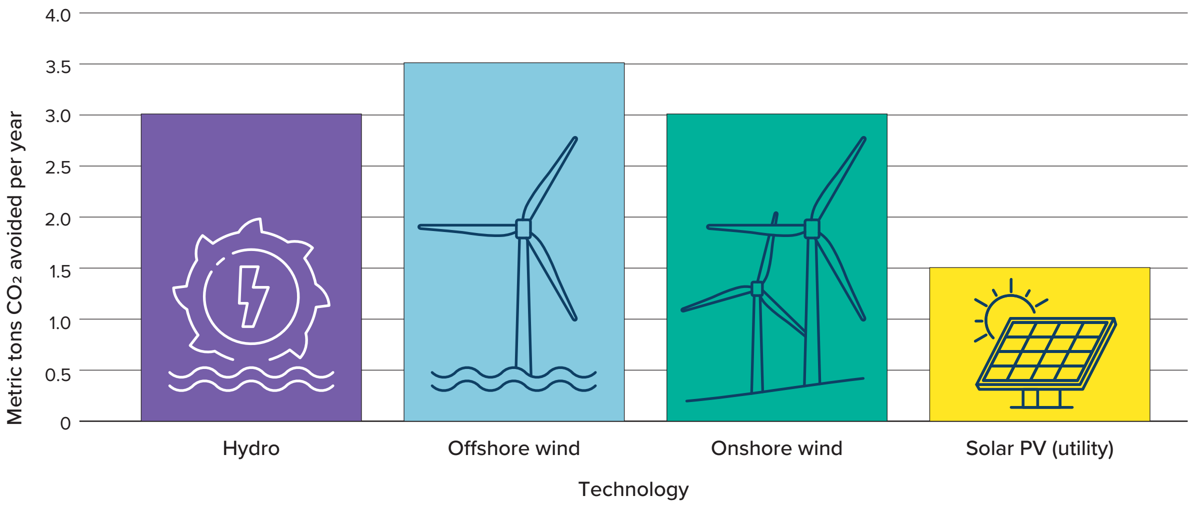
Climate and Environmental Benefits

Offshore wind can play a major role in reducing greenhouse gas emissions and decarbonizing energy systems. The average carbon intensity of electricity generated is 475 metric tons of CO_2 per GWh [7], whereas the lifetime emissions from offshore wind are equivalent to between 5 and 13 metric tons of CO_2 per GWh [18]. As indicated in figure 1.2, offshore wind is one of the most effective forms of variable renewable generation to displace coal, from the perspective of emissions avoidance [19]. This helps countries meet their nationally determined contributions as part of the UN Paris Agreement [20]. Furthermore, it typically takes only 7.4 months of operation for an offshore wind plant to have produced as much energy as it will consume in its entire lifetime [7].

Offshore wind directly contributes to reduced local air pollution and water savings. Offshore wind releases no atmospheric pollutants during operation compared to fossil fuels, which on average release 1.1 metric tons of sulfur dioxide and 0.7 metric tons of nitrogen oxides per GWh of electricity generated [7]. In addition, thermal generation requires, on average, 15 million liters of water per GWh [7] to cool equipment during operations. Offshore wind does not use any water during operations. Like any large infrastructure, offshore wind developments have the potential to give rise to adverse environmental and social impacts. These risks can be avoided through a strategic choice of project location, and careful management and mitigation thereafter (see sections 2.5 and 3.3).

There are already bans on new coal power stations in a range of countries, and more of these will be put in place in the next few years [21]. Countries such as the Philippines[21] [22] and utility companies across the European Union have halted construction of new coal power stations [23], while other countries such as the UK [24], Denmark, Italy, and Portugal [25] have already fixed dates by when no coal generation will be permitted. The IEA has published a net zero roadmap whereby almost 90 percent of global electricity would need to come from renewable energy sources by 2050 [26]. The roadmap forecasts no new oil and gas fields for development beyond projects already committed as of 2021 and has suggested offshore wind as a major contributor to filling the generation gap.

FIGURE 1.2: Comparison of annual direct CO_2 emissions avoided for each 1 GW of renewable energy technology installed (based on displaced coal generation)



Source data: IEA [19].

21 The Philippines has a moratorium on new coal power stations, but this does not apply to plants in later stages of development or construction.

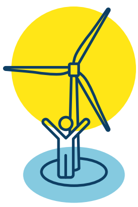
Attracting Foreign Investment

The massive amounts of financing required for offshore wind projects (1 GW typically equates to a capital expenditure [CAPEX] of about US$3 billion) mean that emerging markets will need foreign investment. Local financing markets are unlikely to have sufficient liquidity to be able to finance multiple offshore wind projects alone. An important way for governments to facilitate inward investment is to ensure their policies and frameworks encourage the development of bankable projects that meet international financing requirements.

Offshore wind is viewed as an attractive investment opportunity [27], and with the correct frameworks in place to manage risks, there is a large pool of available capital to finance offshore wind projects. This is being influenced by managers and shareholders of the world's largest banks and financial institutions who are increasingly seeking investment opportunities in low carbon generation [28].

Emerging markets with trade and currency imbalances can benefit from the large volumes of foreign direct investments required for offshore wind projects. The development of offshore wind can therefore provide a valuable contribution to a country's strategic economic objectives.

International financing for offshore wind requires environmentally and socially sustainable development, in-line with Good International Industry Practice (GIIP) [22], global goals for biodiversity conservation and carbon emissions reduction. The World Bank Group launched its Environmental and Social Framework in 2018 [29] and its sister organization the International Finance Corporation (IFC) first adopted its Sustainability Framework in 2006 [30]. Both of these frameworks include clear standards for sustainable development on which lending is dependent and have come to represent international leading practice for achieving sustainable, bankable projects. Projects not meeting these standards will not be considered as bankable and will not be able to attract foreign lending. This critical topic is addressed in more detail in section 2.5. In addition, low carbon projects that align with environmentally responsible investment principles, such as the United Nations Environment Programme Finance Initiative (UNEP-FI) Principles for Responsible Investment (PRI) [31], can attract low carbon investment in ways that investment in generation from fossil fuels cannot.



KEY SUCCESS FACTORS

Related to energy strategies for offshore wind, governments should:

a. Establish a clear role for offshore wind in the country's future energy mix to help meet local electricity demand, and potentially the energy demands of other consumers and markets.
b. Set a long-term energy strategy, considering reductions in the cost of offshore wind over time.
c. Consider the emissions reduction potential and economic benefits of offshore wind, including job creation potential, and integrate it into the country's climate, industrial, and economic strategies.
d. Attract foreign investment by signaling strategic intent and through bankable frameworks including long-term, stable revenue support and environmental and social safeguards.
e. Use the energy strategy to inform the creation of strong policies and frameworks to deliver on strategic objectives for offshore wind deployment.

Suggested reading materials are found in appendix A and full references found in appendix B.

[22] GIIP, as defined by International Finance Corporation Performance Standard 3 (PS3), is the exercise of professional skill, diligence, prudence, and foresight that would reasonably be expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances, globally or regionally [326].

2 POLICY

2.1 Introduction

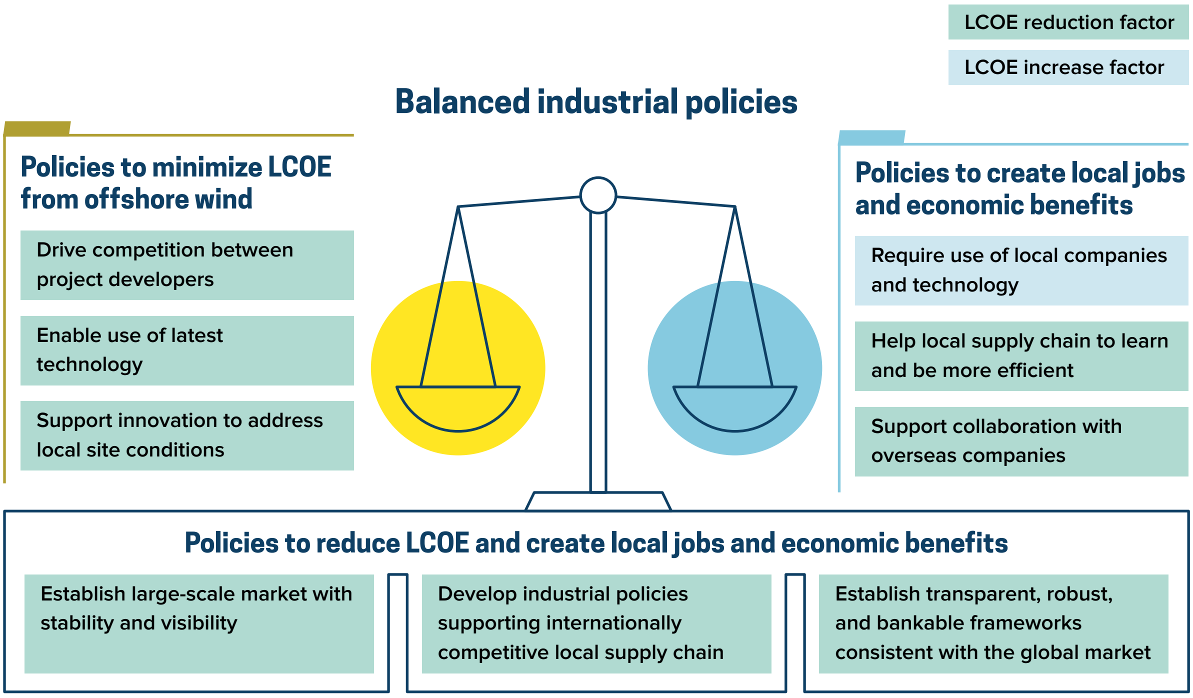
Once a high-level strategy has been established, policymakers must then look to put in place offshore wind-specific policies that will turn the strategy into reality. In forming these policies, policymakers need to answer questions such as:

- How much offshore wind capacity do we want and when does it need to be operational?
- What is a realistic but affordable power price from the first projects?
- What are our long-term costs of energy targets, and how can we help to achieve those prices?
- How do we balance the priorities of job creation and economic benefits with cost of energy reduction?
- How do we maximize benefits to the economy while also ensuring power prices are affordable?
- What is needed to establish a skilled local workforce that also ensures the participation of women?
- What does the government need to do to ensure the local environment is protected, or even benefits from, the development of offshore wind?

Ultimately, to ensure successful market development, policy must provide a clear vision of the government's long-term plans; this can be stated through targets and commitments which, in turn, provide confidence in the market. Offshore wind farms, however, are best delivered at large scale and so, the development of such projects, infrastructure, and associated supply chains can take years to develop; far longer than a typical political cycle. Aspirations, plans, and reasons to facilitate offshore wind deployment need to be clearly stated by governments to help industry deliver. This is particularly important to support supply chain development and cost reduction in this global market. Setting policy also helps to shape the frameworks needed to deliver offshore wind. It is also worth highlighting that the more consensus there is for offshore wind across major political parties, the more confidence the industry will have in that market.

Clear policy targets help drive the work of different parts of government and communicate to industry what government wants. Short-term (5 years), medium-term (5 to 15 years), and long-term (15 to 30 years) targets for installed capacity, job creation, carbon reduction, and other considerations are helpful. These enable different departments and agencies (for example energy, industry, environment, finance, and defense) to develop their own offshore wind plans and to determine the resources needed to deliver them. Targets also enable industry to understand what size market a government seeks and what elements are of greatest importance. Examples of clearly stated policy targets include in the Netherlands' *National Climate Agreement* [33], New York's *New York State Offshore Wind Master Plan* [34] [35], and Japan's *Offshore Wind Industry Vision* [36]. These policy targets were then adopted into legislation, which reduces the risk of targets being removed by a future government.

FIGURE 2.1: Policy balance between cost of energy and local economic benefit in the early stages of emerging markets



Note: LCOE = levelized cost of energy.

Policies need to support the participation of experienced offshore wind project developers. The involvement of companies experienced in offshore wind delivery is key to the growth of emerging markets. They bring the experience of sensitive project development, establish new supply chains, and manage complex construction and operation efficiently, while following the latest health and safety best practices. It is important to combine their experience with local expertise and knowledge to maximize the chances of success.

Governments need to balance several, often competing priorities in determining their offshore wind policies. A key balance is between the levelized cost of energy (LCOE) and local economic benefits, as shown in figure 2.1, adapted from the *Japan Cost Reduction Study* [37]. A common approach to creating local jobs and economic benefit is to require local content[23] as part of development rights (light blue in figure 2.1). However, experience in markets, such as in France and Taiwan, has shown that local content requirements (LCRs) tend to reduce competition, increase cost and risk, and slow market development (see sections 2.3 and 2.4). Rather than mandating LCRs, it is recommended to progress the items shown in green, which enables both a strong market and a strong local supply chain.

Collaboration with industry is key to successfully building and evolving policy. A government's policy objectives and priorities can change over time. Industry needs to understand the government's reasoning and to be given the chance to provide feedback on government plans to ensure that objectives are reasonable and can be met. Case Study 2.1 provides an example of how this has been managed in the UK. As well as working with industry stakeholders, governments often involve impartial, strategic advisers when shaping the detail of policies and implementing the resulting frameworks.

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23 Local content is the value added by the supply chain within a country. It can be quoted as a monetary value or as a percentage of total spend. It is not simply the value of contracts placed in a country, as this may include value added outside the country. See [208]. Requirements may be defined in terms of monetary terms or by listing areas where local supply is required (such as in Taiwan).

CASE STUDY 2.1: Government-Industry Collaboration to Build and Evolve Policy Objectives for Offshore Wind

In the period 2012 to 2020, the UK Government made it clear that its focus was on reducing the cost of energy from offshore wind. It did this by both:

- Setting LCOE targets (in collaboration with industry) [38] [39], and;
- Ensuring that policies prioritized cost competition over creating local jobs and economic benefit.

The industry then reported on the progress of key initiatives, and evidence of cost reduction. This policy was effective, but the government decided to change its policy focus as the industry matured; hence it embarked on a collaborative process with industry to implement that change.

In 2019, the second government-industry "Sector Deal" set the agenda up to 2030, focusing on volume and local economic benefit [40]. This was one of a wide range of similar Sector Deals across a range of industries.

For the period 2020 to 2030, the government has provided targets focused on economic benefit and worked with industry to put in place processes to deliver, including:

- Offshore Wind Growth Partnership [41], an industry-funded long-term business transformation program established as part of the UK Offshore Wind Sector Deal.
- Revised arrangements relating to how local content is considered in revenue support auctions (in consultation at the time of writing).
- The adjustment in policy was helped by significant ongoing communication, much of which was through the Offshore Wind Industry Council (OWIC) [42], which brings together industry, policy makers, and stakeholders to shape the industry.

This journey shows the importance of government collaboration with local and global industry players to help implement policy objectives. Local content policy development is further discussed in Case Study 2.8.

Good examples of clear policy and legislation can be found in the UK and Poland (see Case Study 2.2). Government interventions in both countries have helped increase industry interest and focus, though it is too early to tell whether the majority of targets will be met.

CASE STUDY 2.2: Strong Offshore Wind Policy Drivers and Legislation—UK and Poland

UK Energy White Paper: Powering Our Net Zero Future [43]

In December 2020, the UK government outlined its policy targeting sustainable growth, with the goal of achieving carbon net-zero by 2050. Offshore wind is a key part of the plan to achieve this aim. It sets out a target of 40 GW of offshore wind installed by 2030 and with this, the creation of 60,000 jobs. The strategies have been followed up with accompanying policy and legislation. For example, in the UK, The Crown Estate has set up the Offshore Wind Evidence & Change program, funded with an initial US$35 million, which is delivered in partnership with the government and a wide range of stakeholders. Its aim is to better understand and overcome the cumulative environmental impacts of offshore wind and its impacts on users of the sea and onshore communities. [44]

Polish Offshore Wind Act [45]

Poland's Offshore Wind Act came into force in February 2021. This sets out the rules and regulations that will apply to the development of offshore wind. The act sets out targets for 3.8 GW of offshore wind by 2030, 10 GW by 2040, and 28 GW by 2050. This is an ambitious strategy given that at the time of the act coming into force, Poland had no offshore wind installed and relied heavily on fossil fuel generation, with 70 percent of electricity being produced by coal. Suggested reading materials are found in appendix A and full references found in appendix B.

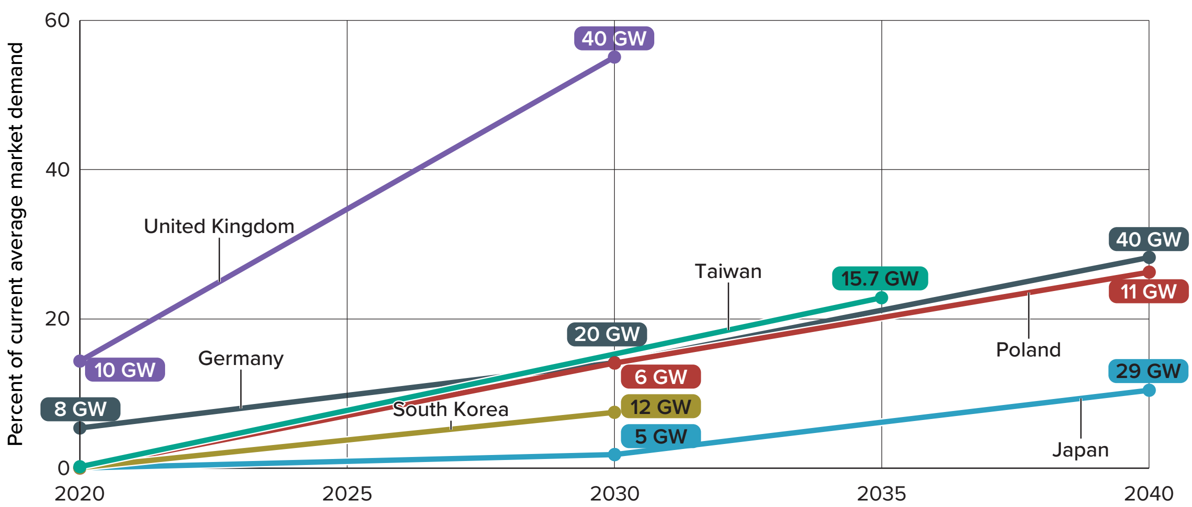
2.2 Volume and Timescales

Governments should carefully consider the amount of offshore wind it seeks to enable and to the timing of the deployment of the new generation capacity.

Volume

Clear, long-term targets for offshore wind deployment volume are helpful in supporting policy statements. Deployment targets 10 years ahead ideally are supplemented with visions looking even further into the future. Examples of countries setting targets to 2040 include Germany [46], Japan [36], and Poland [47]. These targets should be developed with industry engagement and can be conditional on the industry delivering LCOE reduction or local benefits. Building confidence that the government is committed to the large-scale deployment of offshore wind over the long term is also critical to attract the large volumes of international financing needed. Examples of targets are summarized in figure 2.2. It is recognized that market demand will change over the next 20 years based on population, downward pressure based on efficiency, and upward pressure based on electrification of transport and heating. The UK target stands out in this regard, reflecting the UK's offshore wind resource and government ambition. However, the UK market still requires significant progress with international interconnectors and energy system management to enable the target to be achieved.

FIGURE 2.2: Examples of published national offshore volume wind targets, expressed as fraction of current market demand[24]



24 Japan has published targets for volumes auctioned, including a range in 2040 [36]. These have been adjusted to anticipated volumes installed to match other markets, taking a central value of the range for 2040 and noting that it will take each project auctioned a few years to reach installation. Current demand is taken from the latest publicly available International Energy Agency (IEA) electricity consumption data, typically for an annual period between 2017 and 2019.

Countries can also come together to establish long-term regional visions for offshore wind and to collaborate on delivery. An example is the North Sea's Energy Cooperation [48]. Case Study 2.3 provides pan-European and global examples of setting regional visions. Collaboration is especially relevant for countries with offshore wind aspirations of 5 GW or less over a 10-year period. This is because a market of that size is unlikely to deliver large-scale, low LCOE, offshore wind projects on its own, as it will be hard to:

- Support sufficient investment in local supply chain and port facilities.
- Create a competitive market.
- Provide opportunities for the supply chain to learn and reduce costs over time.

CASE STUDY 2.3: Long-Term Regional Visions for Offshore Wind

European Vision

In 2019, WindEurope published *Our energy, our future* [49], a well-evidenced industry vision for 450 GW of offshore wind in Europe in 2050 and a roadmap to achieve that vision.

Taking input from this, in 2020 the European Commission (EC) published a 300 GW target for 2050 as part of its Green Deal [50]. This joined up various country strategies and targets, but also set the agenda for international support for supply chain growth and skills development.

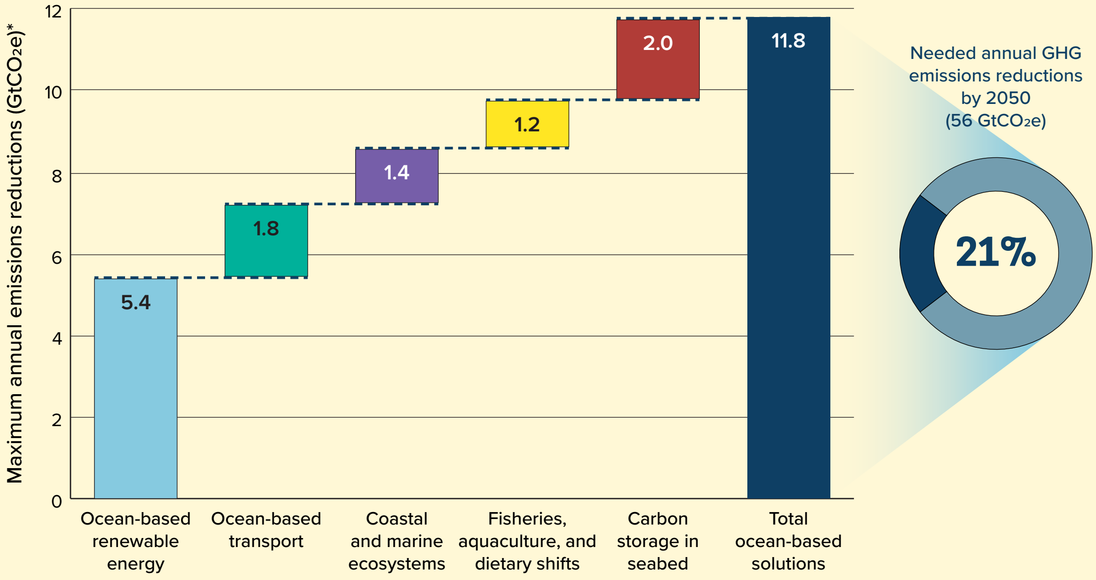
It also stated plans for international cooperation on long-term marine spatial planning for offshore wind and long-term grid planning by regulators in each sea basin. These are the foundations for sustained delivery over the next 30 years.

Global Vision

At a global level, the Offshore Renewable Energy Action Coalition (OREAC) published *The Power of Our Ocean,* an industry vision for 1400 GW offshore wind by 2050 [7]. This industry-led document "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."

It was developed in response to the High-Level Panel for a Sustainable Ocean Economy (also known as the "Ocean Panel") which considered the role of offshore wind in the oceans' contribution to climate change mitigation. As shown in figure CS2.3.1, offshore wind, along with other earlier stage ocean-based renewable energy technologies such as wave and tidal power, have the potential to provide by far the largest single emissions reduction of the interventions considered.

FIGURE CS2.3.1: Contribution of five ocean-based climate action areas to mitigating climate change in 2030 (maximum $GtCO_2e$) [51]



Note: *To stay under a 1.5°C change relative to preindustrial levels.
Source data: The High-Level Panel for a Sustainable Ocean Economy (Ocean Panel) [51].

Its aim was to maximize the benefits of offshore wind globally in a sustainable way, recognizing that will only happen through industry-government partnerships. Publication has led to a range of countries considering their offshore wind opportunities in the context of global uptake.

Enabling a larger pipeline of offshore wind projects typically helps with the balance between the cost of energy and local economic benefit. Coupled with rational policies, achievable volume targets have strong positive impacts in both these areas (see Case Study 2.4). A large pipeline of offshore wind projects can, however, represent a significant financial commitment, including contingent liabilities, which need to be considered. It also drives increased requirement for marine spatial planning in order to manage social and environmental considerations and enable positive coexistence with others in the marine environment. See section 3.3 for further discussion on marine spatial planning.

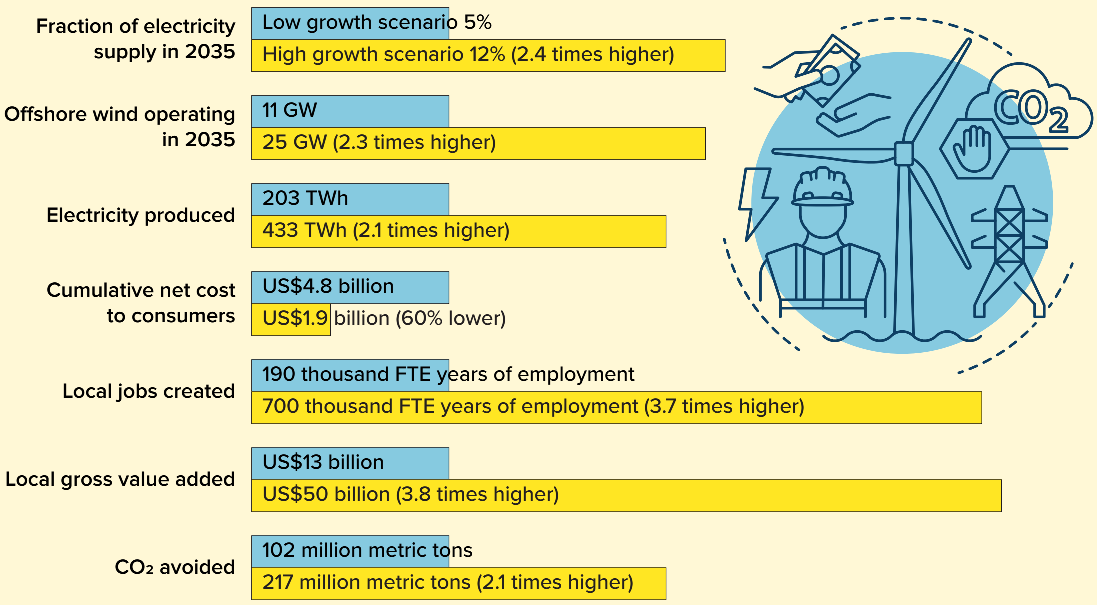
CASE STUDY 2.4: Vietnam: The Positive Impact of Volume on Both Cost of Energy and Local Economic Benefit

As shown in figure CS2.4.1, the World Bank Group's *Roadmap for Offshore Wind in Vietnam* [2] estimates that a doubling of volume capacity targets over a 15-year period could (in the high-volume scenario, compared to the low volume scenario):

- Reduce the cost of energy by a further 20 percent by the end of that period.
- Increase the local jobs created by 3.7 times during the period. Doubling of the volume roughly doubles the number of local jobs. The rest of the increase is due to a higher percentage of local supply and more export potential due to more local investment.

A key finding from this study was that policymakers should recognize that benefits and outcomes from the development of an offshore wind industry may not be linearly proportional to its scale of deployment.

FIGURE CS2.4.1: Impact of offshore wind in vietnam under low and high growth scenarios, 2020 to 2035 [2]



Note: FTE = full-time equivalent; TWh = terawatt-hour.

Source: Taken from Roadmap for offshore wind in Vietnam, World Bank Group, 2021, [2].

Timescales

A steady rate of project delivery maximizes learning and delivery efficiency and helps the supply chain to invest and grow. Suppliers struggle with significant peaks and troughs in demand where they have to rapidly expand and then reduce their workforce. Suppliers that can supply to a range of national markets in a region are better able to cope with varying demand in their home market. For example, Korean suppliers Hyundai Steel Industries and Samkang M&T have recently been supplying jackets to the Taiwan market, while the Korean market has been progressing slowly [52]. Learning by doing has contributed to cost reduction, and this is best achieved by keeping teams regularly building projects together. Governments can play important roles in enabling a steady pipeline of projects through the design of the frameworks that they set up. This should include engagement with industry to maximize the benefits.

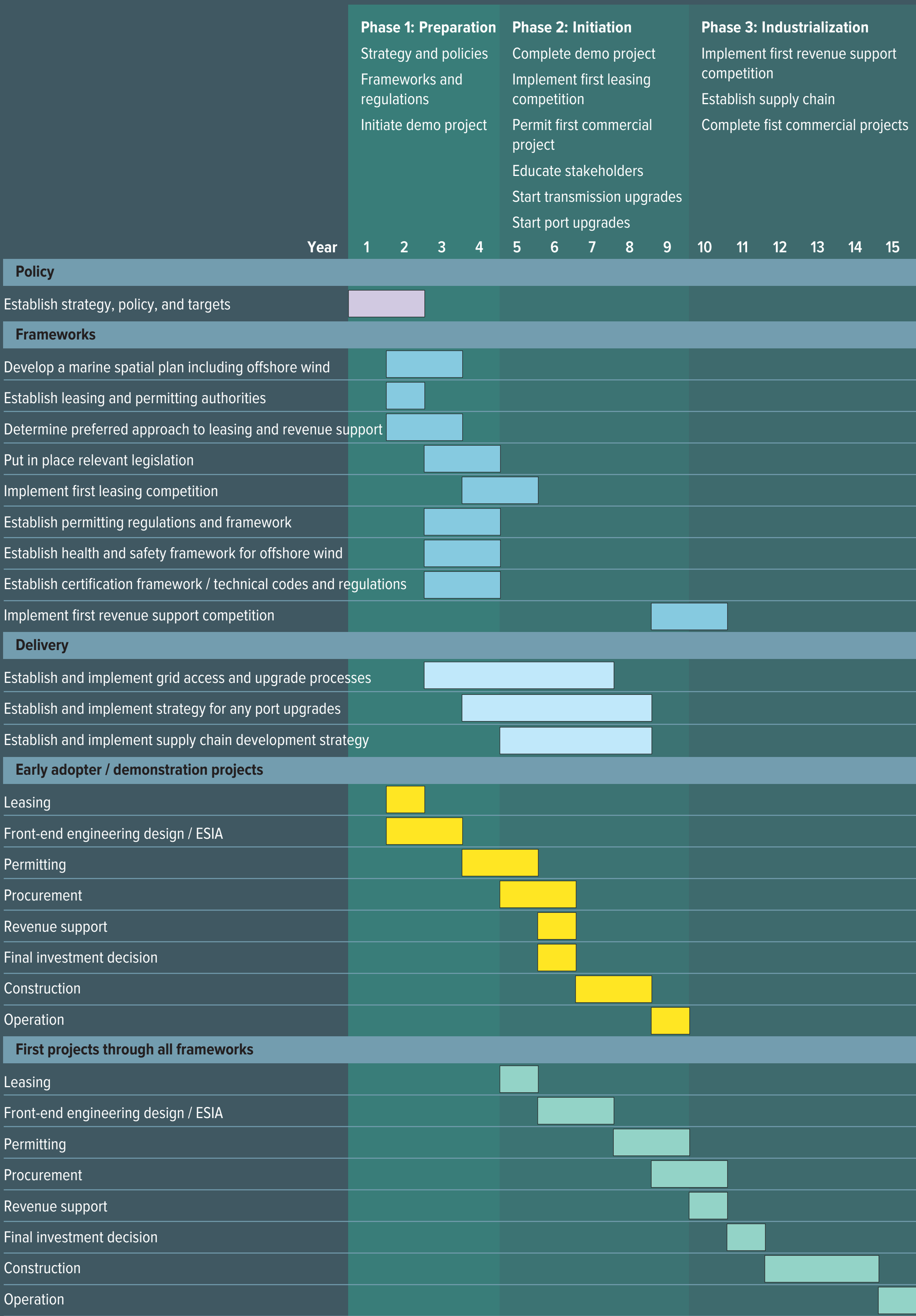
It takes years to establish a new offshore wind industry. To establish frameworks (including via primary and secondary legislation) and build a pool of operating projects can take over 10 years, as shown in figure 2.3 for the case with separate leasing and revenue support competitions. As the global industry matures, timescales will reduce, but uncertainties in new markets could extend timescales. It is important in setting policy to consider, present, and justify reasonable timelines that are in line with industry expectations and capabilities.

Governments can enable early demonstration projects to help start the industry. Smaller-scale, rapidly-deployed demonstration projects can play an important role in:

- Proving new technology and delivery frameworks
- Demonstrating to stakeholders what offshore wind projects are like
- Enabling the supply chain to start delivery at small scale.

These projects may be deployed by developers on the basis of bilateral agreements or competitive processes.

FIGURE 2.3: Example timescales from establishing initial policies and frameworks through to the delivery of the first gigawatt of offshore wind operating in an emerging market



Note: ESIA = environmental and social impact assessment.

Nearly all offshore wind markets have started with a demonstration project. Recent examples include Japan [53], the Republic of Korea [54], Taiwan [55], and the US (see Case Study 2.5). Demonstration projects can however have high capital cost per MW installed, due to relatively high logistics costs and small contract sizes compared to commercial gigawatt-scale projects. As technology matures, there is less need for new technology demonstration via small projects in multiple markets. Instead, mid-sized, early commercial projects (200–400 MW scale) can provide learning and improved frameworks early on in emerging markets, especially if they trigger development of infrastructure (e.g., port upgrades for construction and operation) that can be used for multiple future projects.

Floating offshore wind in deeper water is likely to be installed in larger volume from the late 2020s. This technology will be vital for markets with good wind resources close to population centers, but with water depths over 60 m.

CASE STUDY 2.5: Block Island—The First Demonstration Offshore Wind Farm in the US

Block Island, a small demonstration project of five General Electric (GE) 6 MW turbines has been operating off the coast of Rhode Island state since 2016. Despite the demonstration project being expensive, it has built confidence and understanding that will enable the industry to accelerate, at lower risk. It also helps in identifying issues that need to be corrected prior to full-scale development.

One issue at Block Island was that it used a different permitting route because it is in state waters (as opposed to federal waters), so it did not prove the permitting frameworks for federal waters. It is important to seek to make demonstration projects as relevant as possible to future, commercial-scale projects in the way they are developed, constructed, and operated, as well as in the technology they use, recognizing that permitting for a small demonstrator should be proportionate and hence less onerous than for a larger, commercial-scale project.

KEY SUCCESS FACTORS

Related to volume and timescales for offshore wind, governments should:

a. Provide long-term policy stability and project pipeline visibility to help build industry confidence and ability to invest.
b. Recognize that larger volumes of offshore wind help drive down the cost of energy and grow local supply chain.
c. Create policies based on realistic timescales, considering that it takes time to build an industry.
d. Consider using demonstration projects as a way of kick-starting sector growth

Suggested reading materials are found in appendix A and full references found in appendix B.

2.3 Cost of Energy

Government policies can have a significant impact on the cost of electricity from offshore wind, both in the medium-term and long-term.

Trends in Established Markets

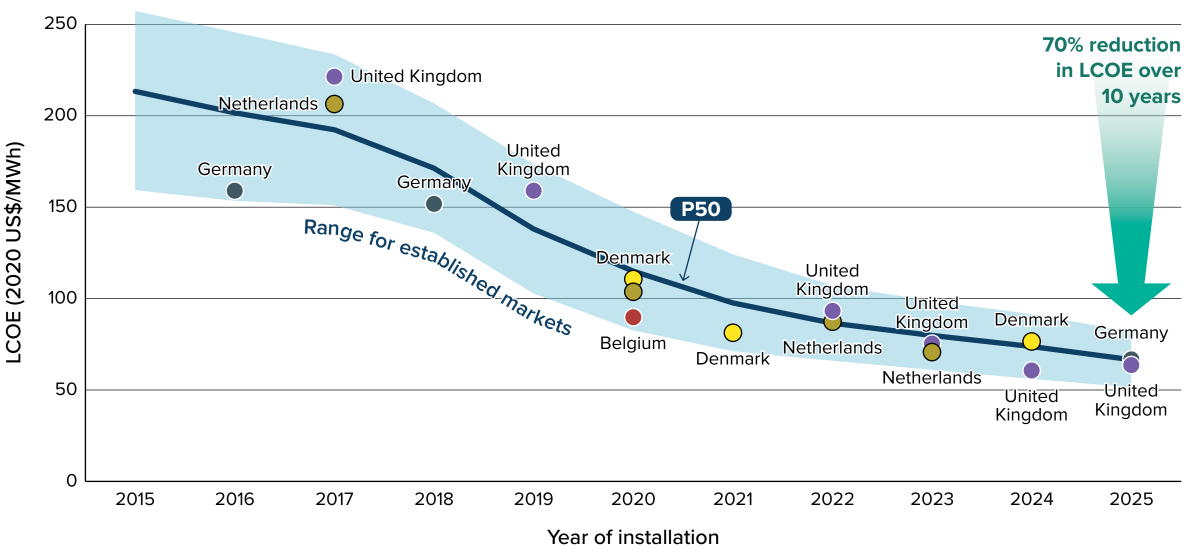
In established markets, there has been a long-term trend in reducing cost of energy from offshore wind, as shown in figure 2.4. The typical range of LCOE[25] is shown as a band. The LCOE is heavily dependent on:

- Site conditions, such as wind resource, export cable distance, and water depth.
- The scale and level of market experience, local content requirements, and competition.

The blue band covers 90 percent of estimated project LCOEs in established markets, incorporating offshore grid connections.[26] Individual projects are shown, where such calculation has been possible. The P50 line[27] indicates average LCOE. In France and Taiwan (markets where local content requirements have been imposed) project LCOEs have been significantly above average due to reduced competition and increased project cost and risk.

Today, floating projects (not shown in figure 2.4) have a higher LCOE than fixed projects, but by the early- to mid-2030s, they are likely to be fully cost competitive as more floating wind capacity is deployed, and risks reduce as the floating technology and supply chain mature.

FIGURE 2.4: Recent Cost of Energy Reduction Trajectory in Established Market (large, fixed sites only)



Source: BVG Associates.

25 LCOE relates to the cost of generation. This differs from the revenue per MWh earned by the developer and the electricity cost to the consumer, which also includes balancing, transmission, and distribution costs.

26 In most cases, a revenue per megawatt hour for a given number of years is published in connection with an auction result. These have been converted into US dollars in the stated year and then adjusted to 2020 prices. LCOEs have then been calculated from results, adjusting for project lifetime and adding export system capital expenditure (CAPEX) and operating expenditure (OPEX) as needed.

27 P50 implies 50 percent chance of exceeding this value. Such terminology is used in the wind industry regarding costs and other key considerations, such as energy production. For example, a P90 forecast of energy production for a site implies a 90 percent chance of exceeding the value (hence is conservative), and a P20 forecast of future installed capacity implies only a 20 percent chance of achieving (hence forecast is optimistic).

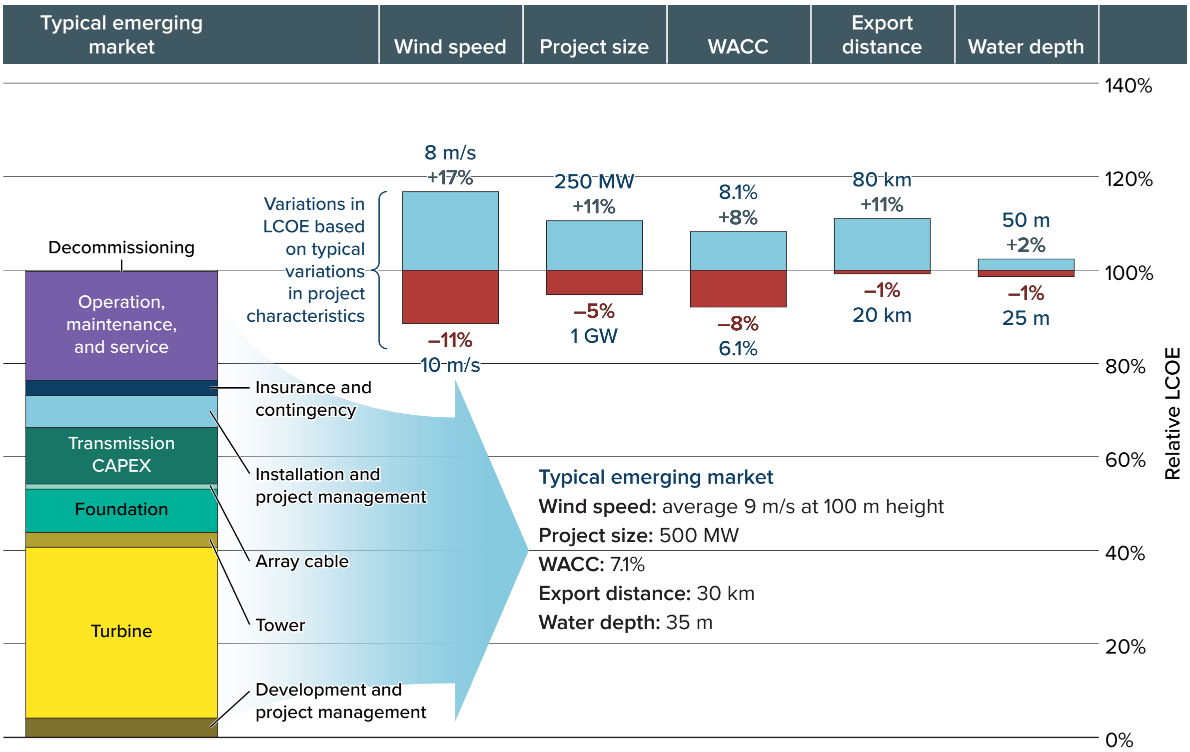
The cost of energy reduction is due mainly to the use of larger turbines, larger scale projects, increased competition, and reduced the project risk. The ongoing trend toward use of larger turbines is because they enable lower cost of energy, especially due to higher energy yield and lower $/MW foundation, manufacturing, installation, and operational costs. Many studies are available that explore the key technologies and market drivers for cost reduction [37] [38] [56] [57] [58] [59] [60] [61] [62]. A key driver in recent years has been competition at the highest level within the supply chain, often driven by competitive auctions. Reduced project risk due to experienced suppliers learning to work well together also reduces the cost of financing, which has a significant impact on the cost of energy.

The key contributors to lowering the cost of energy for offshore wind are:

- Favorable wind resource.
- Use of large turbines in large projects.
- Minimizing cost of finance (WACC)[28] through effective frameworks and well managed project risks relating to site leasing and permitting, through to stable operating revenue from a robust offtake agreement.
- Projects closer to shore and with shorter grid connections.
- Projects in shallower water.[29]

Access to an efficient, competitive supply chain is also key, though the impact is not so readily calculable. The relative impact of these key parameters is explored in figure 2.5.

FIGURE 2.5: Typical LCOE breakdown of a representative project in an emerging market, including impact of key physical parameters



28 Weighted average cost of capital. Overall cost of capital to the project, considering different sources of capital, both equity and debt, and the risks to providers.

29 As shown in figure 2.5, shallower water typically reduces foundation cost, sometimes through enabling a lower cost foundation concept, and sometimes by reducing material use.

Cost Considerations in Emerging Markets

Early projects in a new market will have higher costs, but in subsequent projects this will reduce in the right policy and market conditions. Higher costs for a market's first projects are due to:

- Higher regulatory risks as frameworks and processes are less proven, and some investors may be less experienced, resulting in a higher cost of finance.
- Unexpected challenges in emerging markets, whether environmental (for example, new receptors not previously studied in the context of offshore wind), technical (for example, new ground or seismic conditions not yet experienced in offshore wind), or commercial (for example, new legal or commercial arrangements for offshore wind).
- Early use of some less experienced personnel and suppliers, from early development to the first years of operation. It takes time for supply chains to develop capabilities.
- The distance of countries from existing suppliers and the lack of well-suited port facilities and vessels. To reduce these costs new logistic solutions are sometimes needed, as well as investment in ports and vessels.

Government policy can accelerate cost reduction in emerging markets, (see Case Study 2.6 for a good example from the Netherlands). Governments can do this by:

- Creating market confidence to enable long-term investment in a large, sustainable market by stating clear policies and targets, taking action to deliver these, and communicating well with industry, especially about any potential changes in policy and frameworks.
- Designing frameworks that drive price competition and construction of large projects.
- Reducing project risk for international financiers and developers by creating revenue support frameworks not exposed to inflation and currency fluctuations.
- Encouraging a competitive supply chain high in international collaboration to bring learning from more established markets.
- Enabling competitively priced finance for offshore wind projects through providing robust, bankable frameworks administered by respected and well-resourced organizations.
- Supporting the introduction of the latest technologies and largest wind turbines and helping industry to innovate to address local challenges and continue reducing the cost of energy (see section 4.2).

CASE STUDY 2.6: Netherlands Energy Agreement

The Energy Agreement 2013 proved to be a "game changer" for the development of offshore wind in the Netherlands. It was later supplemented to schedule just over 11 GW by the end 2030 [63].

The agreement was arrived at through a strong public-private process guided by the government, setting parameters for the pace at which the proposed new capacity would be developed, planning and zoning, site investigations, and grid connection.

The confidence created in the forward project pipeline has reduced project risk, financing, and societal costs.

Setting realistic targets for cost of energy reduction helps industry to deliver. Targets can be aspirational, or actual ceilings in future auctions. Examples of governments setting longer-term LCOE targets include Japan [64] and the UK (see Case Study 2.7).

CASE STUDY 2.7: The Crown Estate Cost Reduction Study

In 2012, the UK government sent industry a challenge to reduce LCOE from around US$210 (£150)/MWh to US$140 (£100)/MWh over 10 years. Industry provided detailed technical evidence and set out a roadmap on how it would do this, with recommended actions that defined what it needed from the government [38] [39].

Both the government and industry built confidence in each other and agreed to the UK's first offshore wind industry deal [39], together enabling high volumes at low cost. Industry rose to the challenge and the LCOE target was achieved four years early.

Setting volume expectations linked to LCOE reduction in dialogue with industry was effective in establishing a culture of cost reduction.

KEY SUCCESS FACTORS

To reduce the cost of energy from offshore wind, governments should:

a. Create confidence in the market through clear policies and targets, enabling long-term investment in cost reduction.
b. Encourage a competitive environment through auctions and through investments in the local supply chain.
c. Enable project developers to minimize project risk and attract low-cost finance by developing clear, robust frameworks that enable bankable project delivery.

Suggested reading materials are found in appendix A and full references found in appendix B.

2.4 Local Jobs and Economic Benefit

Offshore wind offers long-term opportunities for local jobs and economic benefits. This section links closely with supply chain development discussed in section 4.2.

Enabling Local Supply Chain Growth

A government's key roles are to help provide industry-level visibility and to put in place policies and frameworks that give suppliers confidence to invest and establish their own pipelines. If a government wants to prioritize local economic benefits, it needs to make this clear in its overall strategy. If it prioritizes cost reduction above local jobs and economic benefits, creation of a large market will also bring much local economic benefit through competitive business practices.

International suppliers are essential to provide competitive tension. Governments should consider local supply in the context of a competitive regional and global market. Apart from China and the US, individual national markets are not large enough to sustain a competitive local supply chain alone. Individual markets can have peaks and troughs and if, for example, a firm needs to supply to 1 GW of projects per year to be competitive, then to make a competitive market of three to five suppliers needs, a pipeline of tens of GWs over 5 to 10 years. This volume can only be provided by several countries in a geographical region, or through global supply opportunities. Governments can respond to this by:

- Focusing on areas of the supply chain where a country is likely to be competitive.
- Establishing frameworks that drive an internationally competitive local supply chain.
- Seeking to enable cross-border supply between markets through reducing trade barriers and harmonizing standards between markets.

It is important to balance requirements for local content with the benefits of long-term, low-cost electricity production. In a global energy transition away from fossil fuels, having an economy built on low-cost electricity from its own resources may be even more valuable than the jobs created directly from offshore wind project delivery. Project developers face many risks developing offshore wind in new markets, even without using suppliers inexperienced in offshore wind. New York has sought to balance these two aspects through its offshore wind power procurement process (see section 3.6).

Countries approach local content in different ways and their strategies continue to evolve. Examples of different approaches are provided in Case Study 2.8.

CASE STUDY 2.8: France, Netherlands, Taiwan, and the UK: Local Content Strategies

There may be no single approach that suits all markets, but the World Bank Group and global wind industry players encourage approaches that minimize barriers and enable broad competition.

France

France's first two auction rounds, where project developers bid for revenue support, had strong incentives to build local turbine component factories, which encouraged consortia led by French developers and included French-owned turbine suppliers, Alstom (since acquired by GE) and Areva (since acquired by Siemens Gamesa), which in 2012 both promised blade and turbine nacelle assembly factories. Planned dates for full operation then were for 2018. Slow progress in delivering these projects has been partly due to the inexperience of the consortia, complexities in permitting frameworks, and late permitting objections.

The extended Round 1 lead times led to a clear mismatch between French prices and those being achieved in auctions elsewhere. This in turn caused further delays as the French government renegotiated prices of contracts with the project consortia in 2018. In 2021, earliest dates targeted for full operation are in 2022.

So far, French facilities established have been underutilized, and their long-term viability is likely to depend on a strong French market.

Netherlands

The Netherlands has driven recent activity through competition between project developers based only on cost (and feasibility of project delivery). The government claims that significant cost savings [62] are due to competition and lack of local content considerations.

Taiwan

In Taiwan, the government imposed strict local content requirements in specific areas of supply that developers must deliver or negotiate on. This has driven the establishment of local supply, but it is not clear if it will be sustained without government intervention. Likewise, the impact of this policy on LCOE is hard to separate from the impact of local conditions, but most recognize a cost penalty.

In 2021, Taiwan announced a softening of its requirements for future projects, giving project developers increased freedom to decide how to deliver local content by adding new items to its list of designated items for local supply, but requiring project developers to source only up to 60 percent of these from Taiwan. [65]

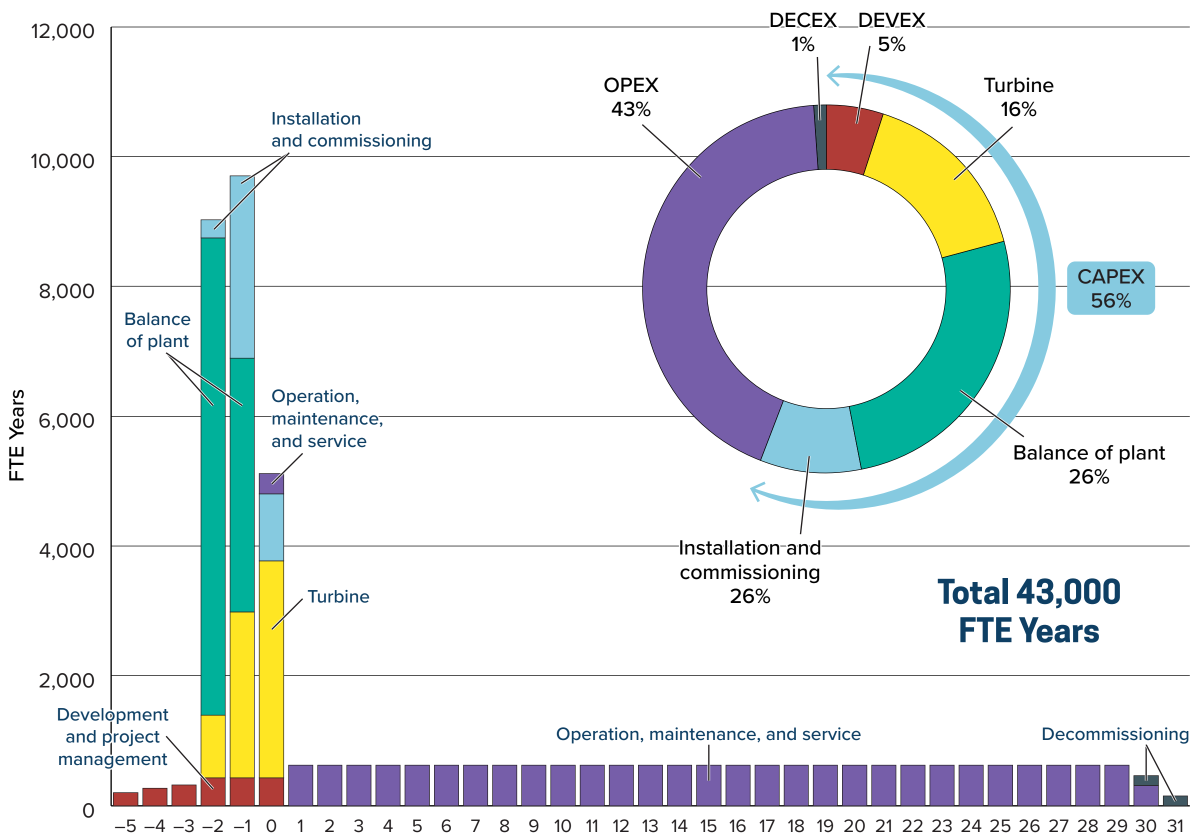
United Kingdom

In the UK, the government did not set a local content requirement in the early years, so as not to risk stifling the industry. Now the market has matured and a sector target of 60 percent local content by 2030 has been agreed (rather than imposing any local content requirement on individual project developers) [40], leaving it to developers to decide the most advantageous way to incorporate local content.

Best Opportunities for Local Economic Benefit

Most employment is during manufacturing and project construction, but important long-term sustainable jobs are also created during the operational life of projects. The distribution of full-time equivalent (FTE) years of employment through the lifecycle of an offshore wind project is shown in figure 2.6 (adapted from *Roadmap for offshore wind in Vietnam* [2]). These jobs are either in the country of installation or elsewhere, depending on local capability. Initially, a new market will have a higher fraction of local content in the operating phase than the capital phase of a project, but the contribution to the capital phase typically increases as local suppliers mature.

FIGURE 2.6: Jobs from a single 1 GW offshore wind project in an emerging market



Source: BVG Associates.
Note: CAPEX = capital expenditure; DECEX = decommissioning expenditure; DEVEX = development expenditure; FTE = full-time equivalent; OPEX = operation expenditures.

An installation rate of 1 GW of offshore wind per year typically uses about 25,000 FTEs in the capital phase (up until the start of operation). Each 1 GW of operating plant uses about 600 FTEs each year.[30]

As an example, for a country installing 1 GW per year of offshore wind and with 5 GW of offshore wind operating, if it has 50 percent local content in the capital phase and 80 percent in the operating phase, it will be using about 15,000 FTEs. As the cost of energy reduces, the number of jobs reduces due to increasing supply chain efficiency, but typically this is offset by market volume growth. The types of jobs involved are discussed in section 4.2.

There are some areas of supply that typically are most appropriate for localization first. These include:

- Project development, as this benefits most from local knowledge.
- Construction ports, as being close to sites reduces cost.
- Manufacturing of items and supply of services already provided to other industries, for example oil and gas platform foundations, subsea power cables, electrical equipment, and installation or operation vessels.
- Manufacturing and assembly of items that are expensive to transport due to their size, such as turbine towers, blades, foundations, and offshore substation topsides, though local supply very much depends on local manufacturing capability and the regional supply strategies of turbine suppliers and project developers.
- Operation and maintenance services, as typically these need to be performed over many years from a port local to each project.

Examples of large items that are appropriate to manufacture locally are shown in figure 2.7.

FIGURE 2.7: Examples of large items that are appropriate to manufacture locally

Note: Images Generally of Items for 10 MW-scale Turbines; Dimensions for Next-Generation 15 MW-scale Turbines. A. Wind turbine blades stacked for transport © Vestas. B. Monopile foundations, courtesy of EEW SPC, © Andreas Duerst, STUDIO 301. C. Wind turbine tower sections, courtesy of GE Renewable Energy. D. Offshore substation, courtesy of Equinor, © Ole Jørgen Bratland.

30 In comparison, an International Renewable Energy Agency (IRENA) study in 2018 [294] estimated that a 500 MW wind farm created about 2.1 million person days (about 10,000 FTE years, or 20,000 FTE years per GW). This was a based on an industry survey and likely to miss jobs created in the lower tiers of the supply chain. It was also based on European working practices.

In many markets, the supply and assembly of turbine nacelle components may never be localized. This is because:

- There is much knowledge of how to ensure highly reliable products held by experienced suppliers in other markets.
- The supply of many subcomponents needs to be localized to make it worth assembling nacelles locally.
- There is little value added through the local assembly of turbine nacelles.

There are several routes to localization of supply. Localization can be from:

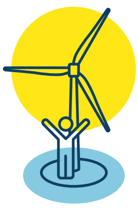
- Entry to the market from a local supplier, for example JDR Cable Systems (array cables) and Tekmar (array cable protection systems) in the early days in the UK or Doosan (wind turbines) in Korea.
- Partnership between a local and international player, for example Century Wind Power (Taiwan) and experienced supplier Bladt Industries (Denmark) to manufacture foundations in Taiwan.
- An experienced, international supplier investing in a new facility, for example EEW (foundations) in New Jersey.

Most countries are less concerned how localization occurs. Industry purchasers generally prefer partnerships or an experienced supplier investing, as this decreases risk. Governments need to engage with industry early and throughout the development of the sector to understand the requirements and to maximize the local supply benefits.

Skills Development and Diversity Are Important

National and local governments can increase local jobs by promoting and supporting workforce training. Finding a capable workforce can be a bottleneck for rapid growth of efficient, high quality suppliers. Governments can help by providing forecasts of workforce needs and providing grants to local technical colleges, training centers, and suppliers setting up offshore wind manufacturing facilities [66] [67] [68]. It is important to provide training at the right time so that the workforce is ready, but not trained too early. Offshore wind offers job opportunities across science, technology, engineering, and mathematics (STEM) subjects, as well as in a wide range of professional services.

Offshore wind offers new opportunities for equality and diversity. As a relatively new sector, offshore wind can set an example on implementing best practice to measure and address ethnic diversity, gender balance, and equality across their workforce [69]. Inclusion of all enables the best candidates to be chosen for the thousands of new jobs created by offshore wind; however, women frequently experience entry barriers [70]. Policy makers, therefore, should set a strategy to support diversity and include more women in the sector. This may need the provision of an enabling work environment with features such as parental leave and flexible working to support the inclusion of women. In the UK, ambitious targets have been set to achieve greater diversity, both in terms of gender and ethnicity [40]. The Women in Wind Global Leadership Program, led by GWEC, provides best practices guidelines for gender diversity in talent recruitment [71].



KEY SUCCESS FACTORS

Related to creating local jobs and economic benefit, governments should:

a. Focus on the largest realistic opportunities for the local supply chain.
b. Balance pressure for local content with providing market volume, visibility, and competitiveness.
c. Consider local supply in the context of a competitive regional and global market.
d. Develop policies aimed at creating confidence to invest.

Suggested reading materials are found in appendix A and full references found in appendix B.

2.5 Environmental and Social Sustainability

Offshore wind projects can have local and wider-scale implications for biodiversity,[31] ecosystem services,[32] and on socioeconomic receptors.[33]

The Role of Governments

Governments should devise policies that incorporate environmental and social (E&S) considerations of offshore wind development. Policies should convey the need for responsible, sustainable, and inclusive development to ensure these priorities are reflected in the creation of planning and permitting frameworks. These policies need to align, and not conflict with national commitments to international treaties and domestic environmental and social policies, such as national biodiversity strategies, marine protected areas, and species protection.

Setting the priorities for marine spatial planning (MSP) is important. It is important to find routes to positive coexistence in the marine space and for stakeholders, including the wider public, to understand and engage with concerns and recognize the benefits. MSP is a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas. It aims to achieve ecological, economic, and social objectives that have been specified through a political process [72]. Proportionate and focused spatial planning[34] of offshore wind projects, following MSP principles, can be used to inform leasing, as discussed in section 3.3. This can contribute to the strategic deployment of offshore wind by reducing permitting risks and by improving developer and investor confidence.

Early sectoral planning based on MSP is essential. Significant impacts can often be avoided entirely if site selection is informed by MSP. Avoidance at this early planning stage is the most effective and lowest-cost mitigation measure available to governments and developers [73].

Governments can proactively commission early-stage, regional-scale baseline studies to fill data gaps. The baseline data gathered could inform spatial planning, sensitivity mapping, and site selection to reduce environmental and social risks to individual projects. Data collection can start early in a market's establishment and even before projects are leased. This can reduce the lead-in time for individual projects, reduce mitigation costs, and facilitate access to international finance. The data collection campaigns should be designed to fill gaps in knowledge or improve understanding, especially if existing data are of poor quality. The Bureau of Ocean Energy Management (BOEM), for example, frequently commissions baseline surveys and assessments for a wide range of biodiversity and social receptors, then publishes the findings to aid developers, stakeholders, and regulators [74].

Environmental and social impact assessments (ESIA) are important for managing environmental and social impacts of offshore wind projects. It is recommended that the scope of the ESIA, including baseline survey requirements, is formally agreed early with the permitting body or other relevant regulators, as discussed in section 3.5. An ESIA should generally incorporate all elements of the project, including onshore export system assets, as well as an assessment of cumulative effects.

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31 For example, habitats, species, and protected areas.

32 The benefits and values that people obtain from natural resources.

33 For example, other sea users and local communities.

34 Effort is focused on the potentially significant impacts of development, with the depth and scope of the assessment being proportionate to the scale and significance of potential impacts.

Key Considerations

Aligning national ESIA requirements with Good International Industry Practice (GIIP) and lender requirements will facilitate access to international finance and reduce delays. Following robust and well-informed early planning, good ESIA will need to:

- Be conducted on the basis of baseline surveys of the appropriate duration (see section 3.5).
- Ensure that a project is designed in accordance with the mitigation hierarchy to avoid and minimize, as far as possible, any potential adverse environmental or social impacts.
- Ensure that any remaining adverse impacts that cannot be avoided or minimized can be restored/rehabilitated or offset to achieve no net loss of natural habitats, or net gain of critical habitats.

There are a wide variety of competing interests in the marine environment, including offshore wind. Good stakeholder engagement (see section 3.2) can help align interests between parties and form a basis for minimizing impacts on the environment and social receptors. Early spatial planning and robust ESIA (see section 3.3) can help manage the wider and local impacts of offshore wind, respectively. Governments should set policies to enable a positive coexistence of offshore wind with other users.

Learning and data sharing should be encouraged to build an evidence base of data relating to environmental and social impacts. To facilitate data sharing in the UK, The Crown Estate established the Marine Data Exchange (MDE), containing a large amount of relevant data [75]. Proportionate baseline data collection and assessment are required to unlock areas for offshore wind development. This can take two years or more to collect, and the process should be factored into government timescales for offshore wind deployment.

KEY SUCCESS FACTORS

Related to environmental and social sustainability for offshore wind, governments should:

a. Devise energy policies that are compatible with existing international commitments and E&S policies, such as marine protected areas.
b. Conduct early spatial planning to balance conflicting priorities and maximize positive coexistence of offshore wind and other users.
c. Engage with stakeholders to understand concerns and explore local benefits of offshore wind.
d. Set policies to manage environmental and social risks through robust ESIA completed to GIIP, including adequate baseline surveys.

Suggested reading materials are found in appendix A and full references found in appendix B.

3 FRAMEWORKS

3.1 Introduction

A government's vision and priorities, communicated through its strategy and policies, need to be enabled through a series of frameworks, as summarized in figure 3.1. The topics discussed in chapter 2 set the narrative for these frameworks and also raise another series of questions for civil servants to address:

- What different frameworks are needed in comparison to other energy projects?
- Which government ministries and departments will be involved in delivering offshore wind?
- What are their roles and responsibilities, and who should coordinate them?
- Where should offshore wind projects be located within a country's waters?
- How can developers apply for the rights to develop a project?
- What environmental and social impacts could be caused and how are they managed?
- How can the needs of different stakeholders be managed to reduce conflicts and improve acceptance?
- What revenue support is needed and how can this help deliver on the policy's cost objectives?
- Who should be responsible for delivering and owning the electrical export system?
- How can projects be developed safely and to an acceptable standard?
- How can the organization of frameworks ensure that relevant developers, lenders, and suppliers are attracted to the market?

As these questions are relevant to multiple public bodies and to industry, it is important that the right parties are involved in the creation of the frameworks and that there is good coordination and communication among these groups. This chapter introduces seven key frameworks, depicted in figure 3.1, which are needed to deliver an offshore wind industry.

Good frameworks reduce risks to project developers, suppliers, lenders, and investors, and encourage experienced parties to the market. Typically, each offshore project will pass through frameworks where a lease, permits, a grid connection, and some form of revenue support are provided before reaching a final investment decision to construct. Project developers then need to work under health and safety and certification frameworks. Good frameworks also provide stakeholders confidence that their environmental, social, or other concerns will be properly considered.

FIGURE 3.1: Frameworks required to deliver an offshore wind industry

Key attributes of good frameworks are:

- Transparency: providing clarity on the process and the priorities; enabling communication and accountability.
- Timeliness: enabling the right projects to progress within a clear time frame, and for industry to build momentum.
- Fairness: ensuring clear decisions are made according to principles of good governance and social justice.
- Robustness: building industry trust that due process will be followed, and outcomes will be bankable.
- Consistency: ensuring frameworks do not change too often and that interfaces between different frameworks are coordinated and logical.
- Proportionality: delivering what is required, efficiently and without excess complication.

It is vital that a country has a robust and transparent legal system. This needs to underpin all aspects of offshore wind, from leasing, through supply chain contracting and revenue support, to enduring obligations including decommissioning.

There is no single "right" way to develop the required frameworks. Each country should start by considering the fitness for purpose of any existing frameworks and legal codes**.**

3.2 Organizing Frameworks

Organization and coordination across government, industry, and relevant parties are required for successful establishment and administration of frameworks.

Approaches to Framework Creation

Countries have approached framework creation in different ways, based on existing governance structures. Considering the fitness for purpose of any existing frameworks is helpful. For example, many countries have frameworks for the delivery of onshore wind. In some countries, such as Scotland and France, aspects such as permitting are devolved to regional or local governments because of the existing framework structure in each country. Typically, given the scale of offshore wind projects, the frameworks are best administered at a national level. Existing organizations that administer the use of the seabed for other industries, such as fisheries or hydrocarbon extraction, should be considered when setting frameworks for offshore wind.

Some countries have chosen to use one organization to provide a "one-stop shop." See Case Study 3.1. Other countries have chosen to keep the administration of different frameworks separate, such as in the UK where leasing (The Crown Estate and Crown Estate Scotland), permitting (the Planning Inspectorate and Marine Scotland) and revenue support (Department for Business, Energy, and Industrial Strategy) are all administered by different organizations. The benefit of a one-stop shop is the ease of communication and good coordination between frameworks. This is especially suited to smaller nations with fewer interactions between different industries. A benefit of having different administrative bodies is that the role and intent of each can be better defined.

CASE STUDY 3.1: The Role of One-Stop Shops Covering a Range of Frameworks

The Danish Energy Agency (DEA) [76] is a good example of a one-stop shop covering multiple frameworks. It has responsibility for public policy, marine spatial planning, seabed leasing, permitting, and offshore wind innovation. Although the DEA does not provide revenue support, it does administer revenue support awards. The competitive process in Denmark combines leasing and revenue support.

The Netherlands Enterprise Agency (RVO) [77] similarly plays a strong centralized role under the Ministry of Economic Affairs and Climate Policy.

This approach is often attractive to industry, but it is not always feasible. For example, countries can devolve decision-making regarding permitting to local organizations. In the US, for example, offshore wind farms are normally in federal waters, and leasing and permitting are the responsibility of the Bureau of Ocean Energy Management (BOEM), while energy policy and revenue support are matters for individual states.

Strong coordination between different framework administrators is key. This includes administrators of leasing, permitting, revenue support, and other frameworks and ministries responsible for energy, environment, and the ocean. This ensures that processes fit well together, and each can cater for the volumes of projects progressing. For example, the UK has a target of 40 GW of offshore wind by 2030, set by the Department for Business, Energy and Industrial Strategy (BEIS). BEIS runs revenue support auctions every two years where volumes can be capped by capacity or revenue support budgets. It will only meet its targets if sufficient leases are made available at the right time, recognizing that some leased capacity may not end up being delivered.[35] The leasing process is administered separately by The Crown Estate in England, Wales, and Northern Ireland, and the Crown Estate Scotland in Scotland, meaning close coordination between administrators is required. Likewise, the planning inspectorate, administering the permitting framework, needs to plan its resources for the volume of projects leased and move to financial close. Figure 3.2 shows the timing of volumes of capacity that need to pass through different frameworks in order to establish a sustained pipeline of projects, highlighting how progress is needed now in order to establish a pipeline by the mid-2030s.

Creating and changing frameworks take much time. It can take two years or more to develop and enact new legislation or to reach a stakeholder agreement on new processes. It is important for countries to facilitate good communication with industry and to plan and implement changes within agreed timescales. This is because any such changes are likely to introduce uncertainty and delay completion of offshore wind projects. These are also good reasons to minimize the number of changes over time.

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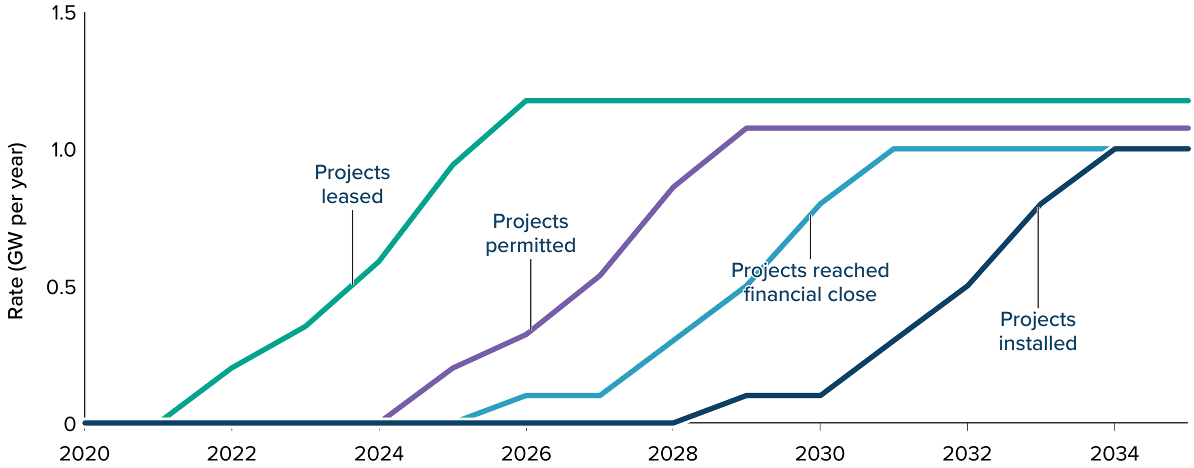
35 For example, projects can fail at the permitting stage, be reduced in MW rating from that originally envisaged, or not obtain revenue support because they have a higher levelized cost of energy (LCOE) than initially anticipated, for example due to lower measured wind speeds or additional costs due to more difficult ground conditions than anticipated.

FIGURE 3.2: Approximate volume that needs to pass through frameworks each year to establish a 1 GW per year pipeline by 2035



Risks relating to frameworks can translate into significant delays. This was the case in France from 2011 to 2017 (see Case Study 3.2) and in the US more recently [78]. Challenges to permitting can also halt projects. This happened in 2021 to the Guanyin offshore wind farm in Taiwan, where the project was unexpectedly denied civil aviation clearance after the project developer had invested significant development capital [79].

CASE STUDY 3.2: French Offshore Experience

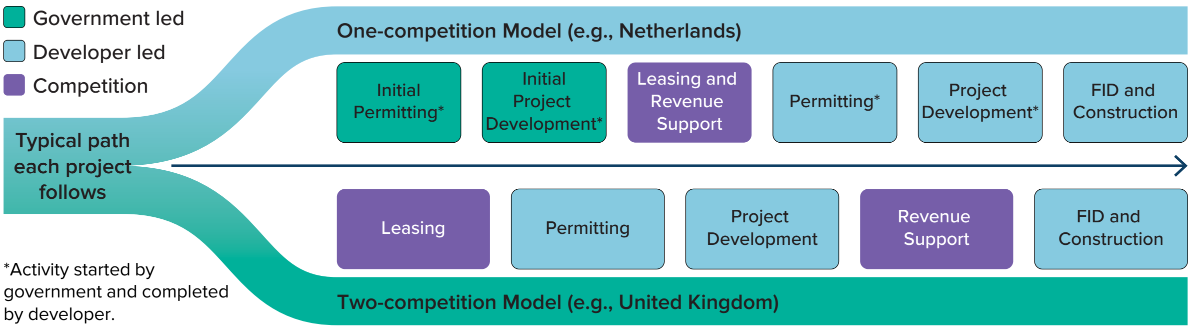
France launched its first offshore wind tender in 2011, followed by another round in 2012, both using existing frameworks which proved inadequate for offshore wind. It was only in 2019 that the first project successfully closed financing. By then, neighboring countries had multi-GW of installed capacity. Many factors contributed to this delay, but the inadequacies of legal and permitting frameworks were key [80] [81].

An update of the legal framework for offshore wind in 2018 and successful negotiations between the government and project developers finally unlocked the industry in France. Almost a decade was lost, but France is now starting to grow a thriving offshore wind industry with a large tender program progressing.

How Frameworks Fit Together

Countries operate different timing of leasing and revenue support competitions. The two key models are shown in figure 3.3, along with key considerations in choosing a model. The one-competition model typically involves the government playing a more active role in early project development so that project developers have enough information to be able to bid knowledgeably for specific sites. Permitting, grid connection, and other considerations typically fit in with these two key stages.

FIGURE 3.3: Overview of frameworks and timing of key competitions in one- and two-competition models



Considerations

One-competition model (compared to two-competition model):

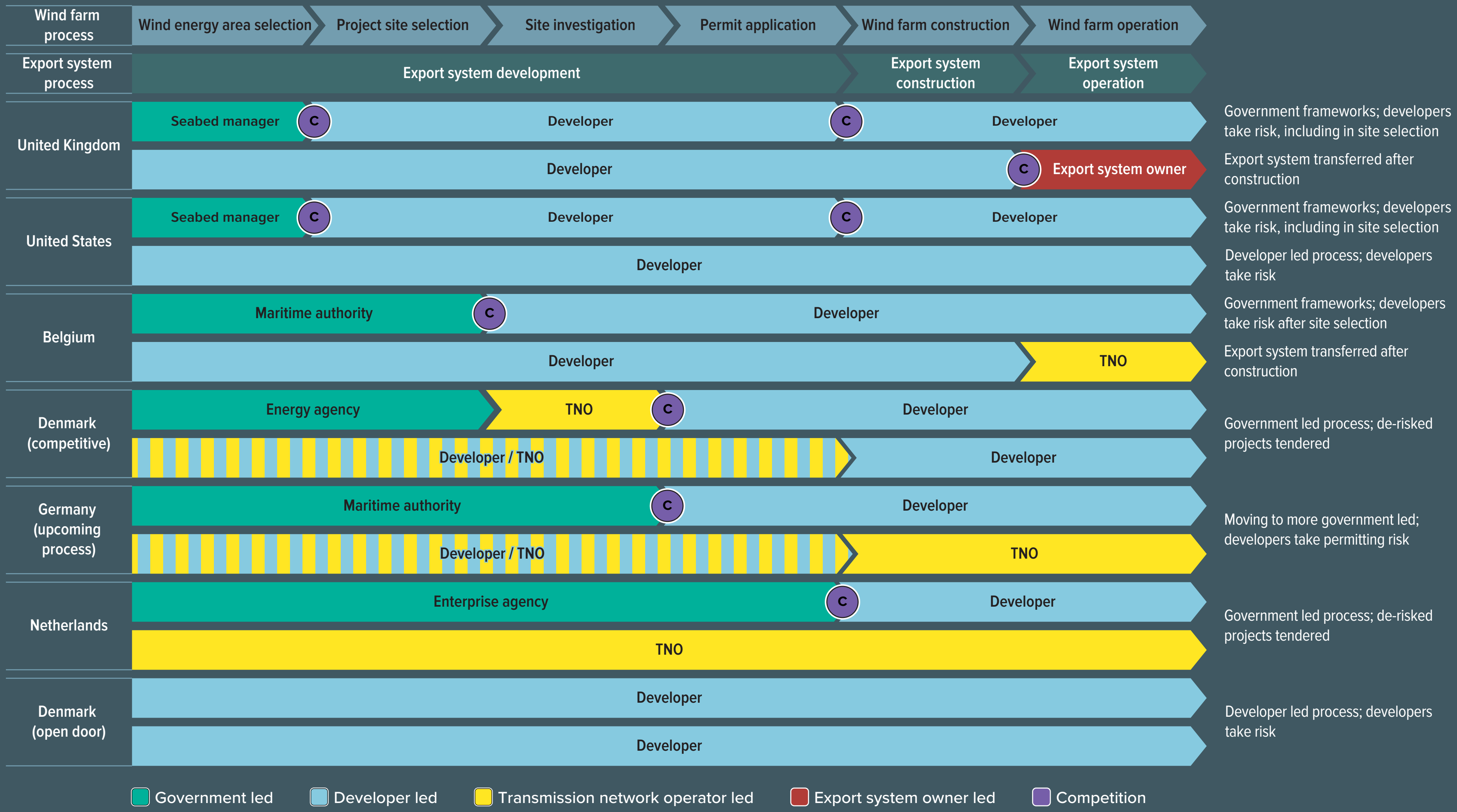
- Gives more opportunity for government to plan efficiently where the wind farms go and when they are installed.
- Does not use competition to find the best sites.
- Has higher risks and up-front cost to government, less to project developers.
- Gives developers less time developing their projects:
  - Less opportunity for relationships to form between developers and local supply chain.
  - Less opportunity for project innovation.
  - Developers do not carry risk of failing to secure revenue support.

Note: FID = final investment decision.

Countries can choose a model based on government roles in other infrastructure projects or can collaborate with industry to develop a model which will work best in its specific circumstances. For example, in the Netherlands the government typically develops infrastructure (the export system), whereas in Taiwan, the UK, and the US, governments prefer industry to take more ownership and risk. Examples of different government, developer, and transmission network operator roles in established markets is presented in figure 3.4 (adapted from [82]).

The choice of model is important, but strong definition and capable implementation of whatever model is chosen is likely to have a bigger impact. Engagement with industry stakeholders, learning from global industry experience (including as discussed in sections 3.3 to 3.8), and support from consulting firms will be important in finalizing plans. The offshore wind industry is still young, and new experience will continue to be shared, leading to an evolving best practice.

FIGURE 3.4: **Different government, developer, and transmission network operator roles in established markets**



Note: TNO (Transmission Network Operator) may also be known as a Transmission System Operator

In a competitive market, leasing and revenue support frameworks offer an opportunity for governments to ensure that their policies are being implemented. For example, governments often want to ensure that leases are awarded to project developers with the capability to deliver the project on time and revenue support is provided to those offering a sufficient level of local economic benefits. Criteria for assessing the capability of developers to deliver projects on time typically include technical and economic feasibility of proposed project design, technical and management experience, and capability to provide or raise finance. Capability assessment typically is before any bid price assessment.

Industry Engagement to Develop Frameworks

Significant collaboration between industry, governments, and wider stakeholders is needed to develop robust, effective frameworks. For industry to be comfortable with the risks associated with investments in offshore wind, it needs to be involved in shaping frameworks. Those within the industry can advise on best practice based on previous international experience. Lessons learned from having worked under different frameworks in different countries can help to accelerate the delivery and can promote cost reduction.

Industry needs to be involved in the ongoing management of the delivery of offshore wind frameworks and needs to have confidence that other relevant stakeholders are involved. As discussed in relation to policy (section 2.1) and delivery (section 4.1), government-industry forums can play key roles in establishing frameworks and ensuring the frameworks evolve as lessons are learned. See Case Study 3.3 for collaboration examples from the UK and Japan.

CASE STUDY 3.3: Government-Industry Collaboration to Develop Frameworks

United Kingdom—Offshore Wind Industry Council (OWIC) [42]

OWIC is a senior government and industry forum and was established in May 2013 to enable a constructive public-private sector dialogue. It is co-chaired by the government's energy minister and an elected senior representative of the offshore wind industry. The OWIC industry members comprise project developers and supply chain firms drawn from the international offshore wind industry. A landmark outcome from the OWIC collaboration was the Offshore Wind Sector Deal [40] in which government and industry agreed on critical industry policy and framework issues, including future auction plans, local content aims, workforce gender targets, export targets, and supply chain investments. See Case Study 2.1.

Japan—Public-Private Council on the Enhancement of Industrial Competitiveness for Offshore Wind Power Generation [64]

This council was established in 2020 by the Ministry of Economy, Trade, and Industry (METI) and the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). The council's members comprise government stakeholders including the Minister of the Agriculture, Forestry and Fisheries, the mayors of related cities and towns, academia, power utilities, offshore wind developers, and the supply chain. The council discusses potential challenges for expanding offshore wind power generation in the mid to long term and has also included engagement on spatial planning to identify preferred development zones. During their second meeting in December 2002, the council discussed and agreed on the government's offshore wind vision including targets for deployment, cost reduction, and local content, as well as key frameworks for planning and auctions.

KEY SUCCESS FACTORS

Related to organizing frameworks for offshore wind, governments should:

a. Start by considering the fitness for purpose of any existing, related frameworks**.**
b. Enable strong coordination between those government entities administering different frameworks to ensure clarity of roles and efficient interfaces.
c. Support strong definition and capable administration of whatever frameworks are established, as this has a bigger impact than the overall choice of approach to organizing frameworks.
d. Engage with industry stakeholders to help establish robust, effective frameworks that mitigate risks associated with investment in offshore wind.

Suggested reading materials are found in appendix A and full references found in appendix B.

3.3 Marine Spatial Planning

As an input to an effective leasing framework, marine spatial planning (MSP) processes, delivered in a proportionate and pragmatic manner, can make a significant contribution to the strategic deployment of offshore wind.

Responsible Use of Marine Resources

The sustainable use of marine resources is mandated by international agreements and captured in United Nations Sustainable Development Goals (UNSDG) [83]. As offshore wind projects form nationally important infrastructure, it is good practice that a strategic approach is made for their location. MSP enables a government to be clear about its priorities. Blue economy [84] and sustainable ocean economy [85] principles (Case Study 3.4) set out the promotion of economic growth, social inclusion, and the preservation or improvement of livelihoods, while at the same time ensuring environmental sustainability of the oceans and coastal areas.

CASE STUDY 3.4: Sustainable Ocean Economy

Commitments have been made by 14 heads of state and governments to achieve 100 percent sustainable ocean management within their national jurisdiction by 2025. These countries are all members of the ocean panel and represent nearly 40 percent of global coastlines and 30 percent of the world’s Exclusive Economic Zones (EEZs) with nations at every stage of economic development [85].

Sustainable ocean management is guided by the Sustainable Ocean Plans framework [86]. The framework sets out five key areas: ocean wealth, ocean health, ocean equity, ocean knowledge, and ocean finance. Each one of these areas details a range of actions to achieve them.

There is growing global support for these principles and solid action in response, both from governments and businesses, with the ocean panel actively encouraging other countries to make the same commitment. It is important for governments to consider offshore wind within the commitments made in this framework.

Using MSP to define the geographical limits of leasing rounds or lease awards for offshore wind is effective in reducing project risk. It helps reduce conflicts with other users of the sea and adverse environmental effects. It also reduces permitting risks faced by individual projects, thereby increasing confidence in the market and attracting experienced project developers.

MSP does not replace permitting, but it does make it a more predictable process. MSP considers environmental, social, and other factors at a high level and helps to consider cumulative impacts of several projects in an area. The permitting process for a given project is then at a deeper level, requiring consideration of more local and site-specific factors.

Governments are in the best place to establish how to balance the use of the marine space within their Exclusive Economic Zones (EEZs)[36] and to lead MSP. The process needs to be collaborative, bringing together users of the ocean and local communities to make informed and coordinated decisions about how to use marine resources sustainably. Current commercial projects with fixed foundations are limited to a maximum water depth of around 60 m. Deeper waters will be used more in the future as floating projects become commercially viable.

The most holistic approach to MSP involves collaboration between countries. Although this is not always possible, it is a good target as volumes of offshore wind increase, especially in the 2030s. Examples of such an approach are provided in Case Study 3.5. Collaboration in an area as complex as MSP can take decades to establish, and deadlines in Europe have been missed [87], possibly because the requirements for European Union plans are more onerous than needed in emerging markets. For emerging markets, the near-term focus should be on proportionate and pragmatic MSP at a national level so as not to unnecessarily hold up early offshore wind deployment.

CASE STUDY 3.5: Collaboration between Countries for Strategic Planning of Offshore Wind

Collaboration is key to balancing uses of marine spaces. Increasingly in Europe, MSP is becoming a joined-up process between countries, enabling regions to be considered as a whole. The European Union's 22 coastal member states were obliged under the MSP directive to develop a national maritime spatial plan by the end of March 2021, with a minimum review period of 10 years and using resources provided through the European MSP Platform [88]. This will, in time, enable a new level of coordination in MSP, but care needs to be taken to avoid this coordination which leads to delays in deployment.

To support this directive, in 2021 a coalition of industry, transmission system operators, and nongovernmental organizations (NGOs) signed a memorandum of understanding (MoU). The purpose of the MoU is to cooperate on the sustainable development of offshore wind while ensuring alignment with nature protection and healthy marine ecosystems [89]. Again, while this is beneficial, it is important to keep near-term projects on course while taking a longer-term strategic view.

At a local level, in September 2020 eight countries around the Baltic Sea, in northern Europe, signed a joint declaration with the European Commission to accelerate offshore wind, with an early focus on collaborative MSP [90].

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36 Each country controls territorial waters to 12 nautical miles beyond its shoreline, but it can claim sovereign rights over resources in up to a 200 nautical mile EEZ. Offshore wind projects have already been developed 200 km from shore (over 100 nautical miles) and with latest operating processes, there are typically no firm barriers to projects further from shore. LCOE increases with distance to ports and for export systems, but other drivers such as wind speed can outweigh these effects, such as for UK's Dogger Bank projects that are in relatively shallow water but far from shore.

Principles of Marine Spatial Planning

The principles of MSP can be followed, and a collaborative process be managed regardless of the level of the data available. The Intergovernmental Oceanographic Commission (IOC) has provided well established guidelines for MSP [72], including a step-by-step approach [91]. The World Bank is developing an Environmental and Social Framework for Offshore Wind Spatial Planning, which [92] describes how environmental and social issues can be considered within the context of strategic spatial planning (see Case Study 3.6).

Limited resources or time pressure may mean that it may not be possible to develop a full, multisectoral, marine spatial plan. Nevertheless, even a limited strategic analysis based on MSP principles, including spatial mapping initiatives, can still deliver significant benefits.

Early-stage technical assessments and sensitivity mapping, using existing available spatial data sets and expert stakeholder input, can be helpful first steps in the spatial planning process. Government-led early planning can involve pre-feasibility–level assessments of potentially suitable areas based on a range of criteria, including wind resource potential, access to the transmission network, and proximity to/interaction with important biodiversity and social receptors. Early planning can often be initiated using existing available data and expert stakeholder input.

The development of a sensitivity map can highlight areas of relatively lower or higher risk, as well as areas of highest risk that are unsuitable for offshore wind development and should be avoided altogether. This approach helps to reduce project risks and avoids the potential for significant and costly delays later in the development timeline, for example to offset adverse biodiversity impacts, or address impacts on/displacement of local community access to ecosystem services. The results can also highlight areas of relatively high risk that would require longer baseline survey periods to sufficiently understand environmental and social risks. This will help to inform site selection and a robust project environmental and social impact assessment (ESIA) (see section 3.5).

Spatial mapping should also consider the economic viability of sites for offshore wind. Spatial LCOE modelling can help to identify the most economically promising areas for development (for examples see work published by WindEurope [93] [49]). Economic viability considers key drivers of LCOE such as wind resource, water depth, distance to construction port, grid connection, and onshore grid transmission upgrades. This can help to focus the spatial planning process by identifying the relevant areas for environmental and social data collection and assessments. It therefore helps to minimize time and efforts spent assessing sites that will not ultimately be economical.

CASE STUDY 3.6: Environmental and Social Framework for Offshore Wind Spatial Planning: A Strategic Approach to Integrating E&S Considerations into Sectoral Planning for Offshore Wind

The World Bank Group (WBG) framework describes how environmental and social issues can be considered within a marine spatial plan, recommends approaches to data collection and analyses, and discusses how marine spatial planning (MSP) for offshore wind could be delivered in emerging markets. MSP, which should be carried out in consultation with relevant stakeholders, should consider activities such as energy, extraction and dredging, cables and pipelines, shipping, aviation (especially radar [94]), and military uses, as well considering environmental and social aspects including fishing, conservation, cultural heritage (including wrecks), and recreation.

The framework envisages that the adopted approach to MSP for offshore wind would vary between countries and regions but would be aligned with evolving good practice, in a proportionate and appropriate manner. While not prescriptive, it recommends consideration of the MSP guidance developed by the Intergovernmental Oceanographic Commission (IOC).

MSP needs to consider export system cable routing and onshore elements of offshore wind projects. Onshore environmental and social issues particularly relate to export cable landfall, transmission cables, onshore substation locations, and other infrastructure such as port development.

Making MSP data available to relevant stakeholders and project developers improves transparency and the efficiency of leasing and permitting processes. Where necessary, commercially sensitive data provided by prospective developers as part of the MSP process are subject to confidentiality restrictions, allowing release after an appropriate time has elapsed.

Ongoing stakeholder engagement is a critical action in the MSP process. It is key to unlocking combined social, economic, and environmental benefits of wind farms while protecting interests of relevant parties. It is used to raise awareness, encourage debate, provide evidence, and set out the decision-making process. It is important that engagement is carried out early and throughout the MSP process as well as for individual offshore wind projects. See figure 3.8 (in section 3.5) for an explanation of relevant stakeholders.

Effective and inclusive stakeholder engagement can be a challenging process. It is important that all relevant stakeholder groups are included in the engagement. While there are some good practices and suggestions for effective processes (see Case Study 3.3), the engagement approach should be tailored to suit the local norms and cultures. An example of a good approach in the Netherlands is shown in Case Study 3.7.

CASE STUDY 3.7: Dutch Communities of Practice in the North Sea

Each country has its own culture and history of stakeholder engagement. The Netherlands tried an evolved approach in response to previous experiences, which provided relevant learning.

The Dutch government estimated that 17 to 26 percent of its North Sea territorial waters would need to be utilized for offshore wind power. The Dutch Community of Practice North Sea (COPNS) initiative was an informal, self-organizing group based on trust and validated by the government, which focused on jointly working toward salient multiuse solutions for water space.

This initiative was different than a formal participatory process and could be considered more inclusive, with 92 percent of attendants advising that the communities of practice meetings met their needs [95].

KEY SUCCESS FACTORS

Related to marine spatial planning for offshore wind, governments should:

a. Use proportionate and pragmatic MSP processes to define the geographical limits of leasing for offshore wind.
b. Follow good practice, including consideration of guidance produced by the IOC and the World Bank Group.
c. Ensure that strategic spatial planning for offshore wind is informed by economic analyses of potential offshore wind sites, as well as environmental and social considerations.

Suggested reading materials are found in appendix A and full references found in appendix B.

3.4 Leasing

To enable the necessary investment, project developers seek exclusive rights to survey and develop a site before constructing and operating a wind farm. These rights are usually given in the form of a lease, which is also known as a concession in some markets.

The Rights to Issue Leases

Each country owns territorial waters that span 12 nautical miles beyond its shoreline, but it can claim sovereign rights in up to a 200 nautical mile EEZ. The United Nations Convention on the Law of the Sea (UNCLOS) is recognized by most governments [96]. Under Article 56 of UNCLOS, sovereign rights include "for the economic exploitation of the zone, such as production of energy from the water, currents, and winds." Governments should only consider the development of offshore wind within a country's undisputed jurisdiction.

Governments need to ensure that local legislation contains provisions to allow the leasing of sea areas for offshore wind projects. Developers will require a lease, underpinned by law, to provide the rights to explore, develop, construct, and operate a project. The exclusive rights provided by this lease give the certainty needed by investors to commit funds to project development and delivery. This legislation should also identify the party responsible for awarding leases. In some countries, processes may already exist to issue seabed rights, particularly for activities such as hydrocarbon and marine aggregate extraction. This can provide a starting point for establishing how to issue leases for offshore wind, but it is important that the process and lease both account for the specific requirements of offshore wind.

Leasing Award Formats

The awarding of leases can take a range of different formats. These are summarized below:

- An ad hoc bilateral process, where a developer asks for a lease.[37] The request is assessed and, if a lease is granted, then it is likely to have time-bound conditions applied, for example, environmental surveys must be completed within three years of award. This can be useful in an emerging market as a way for early projects to be progressed, as has been the case in the Philippines [97] and Vietnam [98]. It has also been used in the UK for innovative projects under 100 MW [99] and early example floating projects [100], and is an option in Denmark for any scale project [101].
- A separate, stand-alone competitive bidding process, providing exclusive rights to develop and eventually construct a given site, as in the UK and the US.
- A competitive process combined with revenue support (in the one-competition model, see figure 3.3). In this process a developer is awarded both a lease and a commitment to revenue support at the same time, as in the Netherlands and Denmark.

Certainty of tenure is important from an early stage. This means that a developer, and any investor it involves, have confidence that no other party will be able to take over the site against its will. The precise legal vehicle of leasing will depend on national practices. Options include:

- A full lease for a given period (with time-based conditions).
- A lease option, or agreement for lease, with an obligation to award the lease once agreed milestones have been met by the developer and only once construction is imminent.

37 Lease is used in this document to refer to the award of rights for offshore wind development, which in some countries (e.g., Belgium and Denmark) is called a concession.

The lease award can be staged, where initial rights are solely for surveys and for project development, with further rights granted based on an agreed process. Increasingly, due to confidence in extended operating life, leases are being issued to cover >50 years (up to 80 years), which can enable project life extension[38] or repowering,[39] allowing developers to plan beyond the current typical 25-year operating life of offshore wind turbines. Such detail likely will depend on national practices in similar situations. It is critical that the lease be considered bankable.

No clearly preferable framework for awarding leases has yet emerged. Key considerations regarding timing of lease competitions are discussed in figure 3.3. Pros and cons of three different lease processes are summarized in table 3.1. To help show the range of leasing activities used, examples of recent leasing processes are shown in Case Study 3.8. If the competition involves bidding lease fees, then it is relevant to note that higher lease fees are likely to eventually be reflected in higher consumer bills, which may price smaller developers out of the market if they are not be able to risk large amounts just to access a single lease, with no certainty of ultimately winning revenue support.

Markets benefit from a pipeline of projects, so it is helpful to have a leasing process which is repeated every two to four years. This provides visibility of project creation and helps developers and framework administrators plan resources. It also creates a smooth pipeline that is beneficial for the supply chain.

Leasing processes should be transparent, robust, and repeatable, and should encourage timely project development. It is important to set a clear process for obtaining leases with defined criteria for establishing who will be awarded a lease. This enables project developers the ability to assess their chances of obtaining a lease, and to consider investing in the process.

These features also minimize the risk of legal objections to leasing. It is critical for a project developer to have confidence that their investments will not be negated by losing their lease. Developers recognize that they need to take a level of development risk, but confidence is undermined if the leasing process is challenged and decisions are changed.

It is important to continue to monitor leasing to ensure processes are delivering suitable volumes of projects and are following evolving international good practice. Leasing is the first stage on a project's journey to operation. If a market seeks eventual installation of an average of 1 GW per year, then an average of at least 1.25 GW of projects needs to be leased 8 to 10 years earlier, as shown in figure 3.2. Whatever arrangement chosen, it is likely that changes will be needed over time to deliver policy outcomes.

It is important that leases are only provided for areas where there is a good chance that offshore wind projects will be constructed. This is where a developer is likely to receive permits and offshore wind is economically viable. Typically, governments in established markets use the results of MSP activities to help define potential development areas.

Leases can be offered for specific sites, or project developers can be asked to propose their preferred sites within large areas. The benefit of offering specific sites is that it simplifies the lease competition, as the risk of overlapping sites is avoided; it also potentially simplifies later permitting activity, as locations can be chosen to avoid cumulative impacts. The downside is that it requires more work up front and limits freedom for project developers to optimize locations. Examples of specific sites and large areas for lease competitions are provided in figure 3.5.

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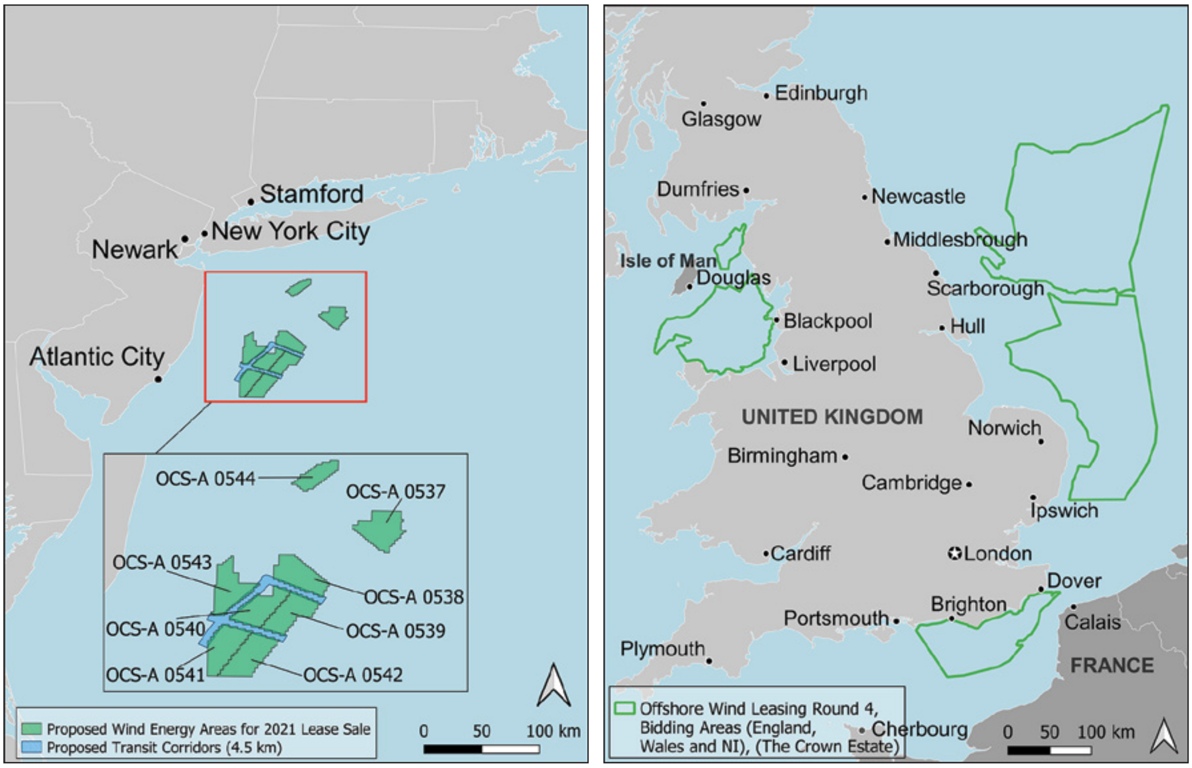
38 Life extension means operating the project beyond its initial design life.

39 Repowering means replacing technology at the end of its useful life with more advanced technology. This can mean old turbine technology is replaced by new, larger turbines on new foundations and connected by new array cables, but potentially using a refurbished export system.

FIGURE 3.5: Examples of specific sites (New York Bight) and large areas (UK Round 4) for lease competitions



Source: Modified from BOEM [102] and The Crown Estate [103].

TABLE 3.1: Comparison of different formats for lease awards

	1 BILATERAL	2 COMPETITIVE (just leasing)	3 COMPETITIVE (combined with revenue support)
DESCRIPTION	Ad-hoc agreement between individual developer and leasing authority.	Competition to award leases early in the project development lifecycle, with any revenue support competition run separately, after permitting.	Competition to award leases late in the project development lifecycle, along with any revenue support.
ACTIVITIES	**Developer:** Early-stage project development to determine site. **Leasing body:** Responds to request and assesses, in isolation to other potential future requests. **Both:** Negotiate terms. **After award:** Developer progresses all stages of project development—design, permitting, purchasing and construction.	**Leasing body:** Decides areas to be leased, preferably using MSP principles (likely to be broad areas, rather than specific project boundaries due to uncertainty at this stage) and manages competition, providing rules and terms of lease. **Developers:** Respond by assessing areas and bidding following competition rules. **After award:** Winners negotiate details of lease with the terms provided, then progress all stages of project development—design, permitting, purchasing and construction.	**Leasing body:** Carries out early-stage project development work (design and permitting) to progress project far enough to define project site and enable project developers to place informed bids with low risk of surprises during final stage of project design and permitting. Manages competition, providing rules and terms of lease. **Developers:** Respond by assessing sites and bidding following competition rules. **After award:** Winners negotiate details of lease with the terms provided, then progress remaining stages of project development—final design, final permitting, purchasing and construction.
PROS / CONS	**Pros:** Can work well to help accelerate early projects in an emerging market. **Cons:** Projects have no framework to work within. Not an effective, efficient long-term route in a market with multiple developers seeking projects in the same or similar locations.	**Pros:** Less effort and cost for government than option 3. Gives developers most freedom in design of their projects—they should know best about how to develop lowest LCOE projects. Developers own project for longer—more freedom to speed up / slow down development of any project in their portfolio. **Cons:** Government does not prescribe exactly where projects will go. Extra process (and risk for developers) for revenue support once developers understand LCOE of project better. More risk to developers relating to permitting.	**Pros:** Government in full control of where projects will go, and when they will be constructed. Single competitive process to manage. Governments de-risk projects further for project developers by considering permitting in detail (including cumulative effects of multiple projects) before leasing. **Cons:** Government has to manage early development work, up to leasing specific projects. This requires more effort and cost for government than option 2. Little room for project developer to make project design decisions or prioritize between projects. Excludes smaller, more entrepreneurial developers.
EXAMPLES	Colombia, Korea, Philippines, Vietnam (early project(s) only)	Taiwan, UK, USA	Denmark, Germany, Netherlands

CASE STUDY 3.8: Example Leasing Arrangements in the Netherlands, Taiwan, the UK, and the US

The following examples are listed to show the range of leasing arrangements used, rather than to suggest that any arrangement is better than another.

Netherlands Round 5 (2019–2020) [104]

From 2019–2020 a single 0.7 GW project (*Hollandse Kust Noord*) was leased in the Netherlands; this was combined with revenue support and managed by the Netherlands Enterprise Agency (RVO). There were two bidders for a well-defined site that had already been surveyed and partly developed and permitted on behalf of the Netherlands government. Previous auctions required bidders to state their required subsidy revenue per MWh. These led to zero-subsidy bids,[a] requiring a different mechanism to decide the winner for this auction. In this auction, after a basic assessment that each bidder could deliver the project within four years, a list of transparent and nonsubjective evaluation criteria was used to assess the quality and cost effectiveness of the wind farm.

A set of lease fees and rental costs were independently set. A single winner was subsequently chosen. This demonstrates how leases can be awarded without price competition.

Taiwan Phase 2 (2015–18)

In 2015–18, Taiwan ran a large, 5.5 GW leasing round with high competition, combined with revenue support. To compete in the process, developers had to obtain a preliminary approval of their environmental impact assessment from the Environmental Protection Administration (EPA). Of the 5.5 GW allocated, 3.8 GW of grid capacity was allocated through a selection process and 1.7 GW was awarded through a tariff bidding process. The selection process used a set of criteria, including stringent local content considerations, to select winning bids. The tariff bidding process was awarded to the bidder with the lowest offtake tariff. Projects that came through the selection process received more than double the per MWh price compared to those that came through the tariff bidding process.

There were 15 winning projects developed by four developers and four consortia. The parallel process suggests that price competition with reduced local content focus helped to lower costs to consumers, while seeming also to favor developers that had been allocated significant volume previously.

UK England and Wales Round 4 (2020–21) [105]

In 2020–2021 the UK ran a large, 8 GW leasing round with high competition, separate from revenue support. This was managed by The Crown Estate and gave developers the freedom to bid their own choice of lease areas within a set of four large zones defined as suitable for offshore wind development.

After a prequalification process based on capability to deliver, developers provided closed bids of annual per MW lease option fees, payable for as many years as necessary until they completed the wind farm design, secured permits, and were able to commit to build the project. There was a complex process to limit what any bidder could win to ensure a spread of projects between zones and to deal with the potential for projects to overlap.

There were six winning projects developed by four winning consortia. This was the first large-scale process that The Crown Estate had run where option fees were the key consideration, and it yielded much higher option fees than anticipated. It is relevant for governments to note that such fees are likely to ultimately be reflected in consumer bills, so the process should be discouraged.

US Federal Lease Auction for Sites off Massachusetts (2018) [106]

In 2018, the US ran a leasing round with high competition, separate from revenue support. This was managed by the Bureau of Ocean Energy Management (BOEM). There were 11 bidders for three defined lease areas. After a prequalification process based on capability to deliver, developers bid a lease fee in multiple, escalating rounds with visibility of how many other players bid, until a single different bidder was left for each lease area.

There were three winning projects totaling up to 4.1 GW capacity developed by three winning consortia. Lease fees equated to a few percent of LCOE, lower than in the UK example.

a. Zero-subsidy bids mean that the developer has closed the gap between bid price and expected electricity price, meaning that the offshore wind project is cost competitive with the merchant market. In Germany and the Netherlands this has been possible because the developer does not have the costs involved with building the export system for the project.

Governments can use a combination of lessons learned from other countries and look at existing internal processes. Many countries already have parallel processes for managing rights to oil and gas reserves or aggregate extraction. These can form a useful basis for the design of a leasing framework for offshore wind.

Leasing processes need to cover cable routing and any other relevant considerations. This can be incorporated into project leasing or be conducted separately, depending on national processes and eventual ownership of offshore export systems. In the UK, project developers manage construction of offshore export systems, then sell these assets after the first operation in an auction (see Case Study 3.22). Leases for cable routes are provided by The Crown Estate but in a noncompetitive arrangement once project leases have been awarded [107]. Leases and land ownership considerations are also relevant for onshore aspects of grid connections, as any potential barriers to timely completion of the export system could have a significant impact on project viability.

Administering the Leasing Process

Leasing needs to be administered by a well resourced, trusted organization. A leasing competition in established markets typically takes two years from announcement to award. In this time, the organization needs to:

- Provide all relevant competition information, including clarity regarding objectives.
- Engage early with key stakeholders to brief them and listen to their views.
- Ensure that bidders have had a chance to ask questions about the process and understand the answers.
- Ensure that bidders have had time to understand risks and opportunities sufficiently to put in positive bids.
- Manage a secure, robust, and fair assessment process.
- Administer the results process and follow-up activities with successful companies.

A logical option is for a government to give additional responsibility to an existing organization managing similar activities in another industry, for example mineral or hydrocarbon extraction. In the US, the Bureau of Ocean Energy Management (BOEM) was chosen to manage offshore wind leasing and permitting. Its role is discussed in Case Study 3.9 to help show what sort of organization is best placed to administer leasing.

CASE STUDY 3.9: The Role of the Bureau of Ocean Energy Management in the US

BOEM is an agency in the U.S. Department of the Interior (DOI) responsible for managing development of the nation's offshore resources in an environmentally and economically responsible way. It is responsible for managing the granting of leases, easements, and rights-of-way for orderly, safe, and environmentally responsible renewable energy development activities, such as the siting and construction of offshore wind farms on the outer continental shelf (OCS), seaward of state coastal waters.

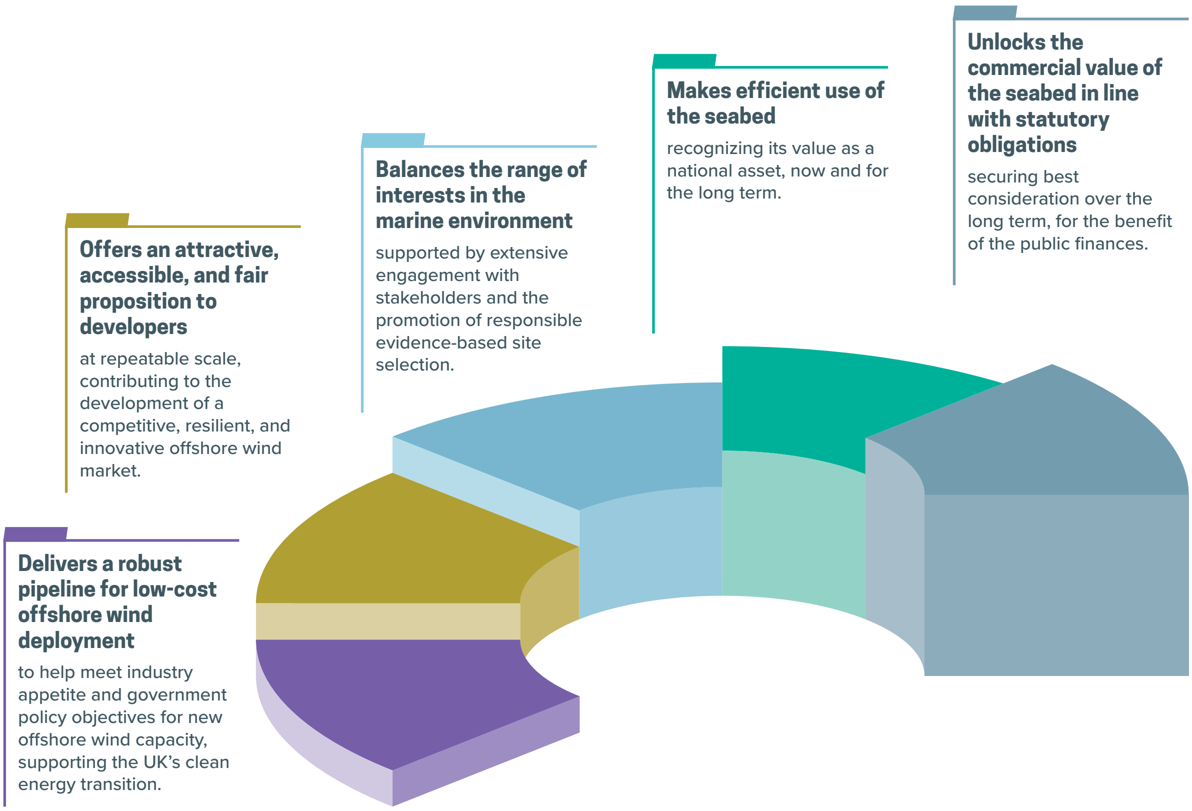
Key mandates include safety, protection of the environment, coordination with affected state and local governments and federal agencies, fair return for use of OCS lands, and equitable sharing of revenue with states. It provides transparent guidelines and details of stakeholder engagement, along with the status of specific leasing competitions, which to date have been state by state.

Full details are available via its website [108], including national and regional guidelines [109].

BOEM has gained the respect of the industry in communicating clearly and administering robust processes with independence and due regard to stakeholders.

Project developers invest significantly in securing leases, and the administering organization needs to lead the process proactively in a way that gives developers and other stakeholders confidence and minimizes the risk of later legal recourse. As an example, The Crown Estate provided good communication about its recent UK Round 4 lease competition and managed a robust, bankable process [105]. Examples of this communication are provided in figure 3.6 and figure 3.7.

FIGURE 3.6: Objectives of the UK Round 4 lease competition



Source: The Crown Estate [103].

FIGURE 3.7: Typical leasing process, based on The Crown Estate's Round 4 [103]

Stage 1
Consideration (3–4 months)
Aim:
The aim of this stage is to ensure potential bidders have all the information required to understand the process and clarify requirements.
Typical steps:
The leasing body provides all relevant competition information to the market, including objectives, process, timeframes, and rules for the competition.
This may include the leasing body hosting market information days, providing potential bidders an opportunity to ask questions, and directly engaging with the leasing body.

Stage 2
Prequalifications questionnaire (PQQ) (5 months)
Aim:
The aim of this stage is to filter the number of potential bidders and ensure that only those with the relevant capabilities submit bids.
Typical steps:
The leasing body issues a PQQ to the market.
Potential bidders respond to the PQQ, and the leasing body assesses the potential bidder's financial capability, technical experience, and legal compliance.
Successful bidders prequalify to the next stage of the competition.

Stage 3
Invitation to tender (ITT) (1 month)
Aim:
The aim of this stage is to evaluate tender submissions against competition requirements.
Typical steps:
The prequalified bidders are invited to submit a tender.
The tender is evaluated by the leasing body via an assessment of the financial and technical robustness of the bid.
The tender process may be multistaged.
Winners are notified and progress to the next stage.

Stage 4
Agreement for lease
Aim:
The aim of this stage is to secure an agreement (or option) for lease with the winners of the competition. This agreement provides the winner with exclusive development rights to an area of seabed, thereby providing the security required to invest in the project's development.
Typical steps:
Winning bidders proceed to negotiate the details and terms of the lease with the leasing body.
Following negotiation, a lease is awarded and signed by both parties.
The agreement is conditional on a project receiving all necessary permits.

Source: Based on The Crown Estate [103].

The leasing body is in a good position to address national issues that support offshore wind projects in development. BOEM in the US, the Netherlands Enterprise Agency, and The Crown Estate in the UK all undertake various studies and wide stakeholder engagement. National topics tackled have included proximity of telecom cables with offshore wind cables, crossing agreements with coastal railways, coordinating public/private funding of joint industry projects, and facilitating sharing of best practice.

Lease Terms

Lease terms need to encourage project developers to keep projects progressing, where possible. Any award of rights needs to be timebound, with developers required to show progress through key milestones to preserve their rights. This avoids any leaseholders holding seabed area, or land, without progressing development, as this could slow down the growth of the industry [110]. The lesson learned in the UK is that a few high-level key milestones are sufficient. Agreements for lease[40] have milestones for initial site development within 18 months, i.e., the start of geophysical surveys, the start of bird surveys, or the submission of a scoping report for environmental impact studies and for permitting application within five years. Later milestones connected with a lease agreement include the start of project implementation within one year and work completion, tied to commitments made when securing revenue support.

Leasing fees need to reflect government intent regarding offshore wind. If a lease competition is being run separate from a revenue support competition, it is important to recognize that there are still permitting and revenue support hurdles to address, and any additional leasing costs built into the process are likely to add to costs when finalizing revenue support.

40 An agreement for lease (1) refers to a contract between parties to enter into a lease agreement (2) at a later date. The agreement for lease (1) places a contractual obligation on the parties to enter into the lease agreement (2), either on a fixed date or based on the satisfaction of conditions set out in the agreement for lease.

TABLE 3.2: Examples of rental fees (not including other fees) for offshore wind leases [111] [112] [104] [113]

Country	Public agency	Project phase/ element	Rental	Units
England and Wales	The Crown Estate	Operation	2%	Of gross revenue[41]
Netherlands	The Central Government Real Estate Agency	Operation	€0.98 (US$1.15)	Per MWh[42]
		Construction	€650 (US$763)	Per MW per year
		Array cables	€3.29 (US$3.86)	Per m^2 (single, one-off payment)
Scotland	Crown Estate Scotland	Operation	£1.07 (US$1.48)	Per MWh[43]
United States	Bureau of Ocean Energy Management	Construction	US$3.00	Per acre per year
		Operation	2%	Of gross revenue
		Export cable	US$70.00	Per mile

Typically, beyond an initial lease fee (or option agreement fee), there is also a land rental fee to start paying when the wind farm is operational (or was planned to be operational), which is either a fixed amount per square kilometer (sq km) or per megawatt (MW) or per megawatt-hour (MWh) or percent of gross revenue. Table 3.2 provides examples of rental fees in a number of countries.

Lease periods need to reflect project development and operation timescales. It takes 5 to 10 years before a project starts operation, and typical offshore wind project operating lives are now anticipated to be between 25 and 35 years, as technology mature operating life is increasing. In most markets, new leases allow for 25 to 30 years of operation. Recent leases in England and Wales have been provided for up to 80 years to allow for a second generation of offshore wind technology to be installed on the site [110]. This enables a cost-effective future project on the same site that benefits from previous site knowledge and uses existing infrastructure. It is therefore valuable to a project developer to have this option.

Leasing agreements provide an opportunity to commit developers to activities that benefit the wider industry. For example, in the UK developers are obligated to provide all survey data to The Crown Estate, which in turn is curated in the Marine Data Exchange [75]. Provision of wind resource measurements can be delayed two or more years to protect bidders in auctions. Free access to this body of data is used to inform future offshore wind development and other sea users.

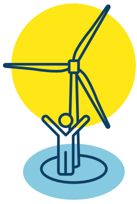
Another obligation is for developers to share health and safety (H&S) incident data into an accredited industry system [114]. The data are valuable in reporting industry-level H&S performance, which in turn sets priorities for areas of improvement.

Lease obligations should include decommissioning requirements. These should include development of a decommissioning program (covering removal of or making safe offshore wind components, and environmental monitoring). In the UK, the government also imposes requirements to avoid any project owner from defaulting on their obligations and leaving the cost of reinstatement to the public [115].

41 Eighty percent minimum output.

42 For area within 12 nautical miles, index linked.

43 Price is index linked.



KEY SUCCESS FACTORS

Related to leasing for offshore wind, governments should:

a. Set out a transparent, robust, and repeatable leasing process.
b. Ensure leasing is administered by a well-resourced, trusted organization for timely, bankable outcomes.
c. Monitor leasing to ensure processes are delivering suitable volumes of projects to meet future delivery targets and are following evolving international good practice.

Suggested reading materials are found in appendix A and full references found in appendix B.

3.5 Permitting

The process of providing all permits to survey, construct, operate, and decommission is critical to project delivery.

Permitting Process

Typically, permitting consists of:

- Environmental and social impact assessment (ESIA) (including an appropriate period of baseline surveys).
- Stakeholder engagement.
- Gaining approvals.

Government's role is to ensure that there are frameworks in place to enable fair and well considered permitting decisions. In established markets, developers can spend more than $100 million before a project has all the permits required to construct and operate [116] [117]. Even when governments lease pre-developed sites, developers need final permits relating to the specific design of the project. Lack of clarity and any over-onerous permitting requirements add significant risk to this spend and delay the eventual project operation, increasing LCOE.

International lending requirements could influence the permitting process. In order to obtain financing from international lenders, projects need to meet Good International Industry Practice (GIIP) standards such as International Finance Corporation (IFC) PS6 [118] and World Bank ESS6 [92], which include specific environmental and social requirements. If national permitting requirements are not aligned with international lender requirements, this can delay or even preclude permitted projects from proceeding. For example, IFC PS6 requires that projects must achieve no net loss of natural habitats and a net gain of critical habitats.[44] Aligning with GIIP standards allows developers to understand the most important issues to address in ESIA and gives a useful early indication of the scale of mitigation requirements of a project. As well as informing the scope of the ESIA, this information can also influence project feasibility decisions before the permitting process is too far advanced. International lending requirements are discussed further in this section.

Administering the Permitting Process

Permitting needs to be administered by a well-resourced, trusted organization. Permitting for a project in established markets often takes one to two years from application (after a developer has completed the necessary baseline studies, and completed all the necessary documentation) to award. Project developers advise that a one-stop shop for permitting is extremely helpful in enabling an efficient process. This means that project

44 Critical habitats are the highest value areas in the world for biodiversity and ecosystem services.

developers deal with one organization that manages responses from all stakeholders. With multiple projects passing through the permitting process in parallel, this enables more efficient communication and resource management. The administering organization of a one-stop process needs to:

- Engage early with developers considering applying for permits and keep stakeholders informed of the upcoming workload.
- Engage early with stakeholders and ensure all are aware of key considerations.
- Assess documentation from a developer and make early requests for clarifications.
- Manage assessment and responses from stakeholders, ensuring that they are informed about the latest information.
- Manage additional information requests to the developer.
- Keep the ultimate decision-making body (often a government minister) informed about the status of permitting.
- Make a final recommendation to the decision-making body, including any conditions required to protect the environment and affected communities.[45]
- Administer any appeals process.

An example of an organization that plays this role well is the Planning Inspectorate (PINS) [119] in the UK (see Case Study 3.10 to understand more about its processes). A well administered process creates an environment where industry has confidence in timely, fair decision-making and stakeholders have confidence that they are heard and have influence.

CASE STUDY 3.10: The Planning Inspectorate in the UK

In England and Wales, offshore wind farms with an installed capacity greater than 100 MW are defined as nationally significant infrastructure projects. This means permitting of offshore and onshore infrastructure is considered at a national level. The permitting process is managed by the Planning Inspectorate (PINS), which is part of the central government.

Offshore wind project developers will typically take at least two to three years to gather the required environmental and social baseline data, make assessments of potential impacts, consult stakeholders, and develop approaches to manage and mitigate issues. This process is expensive and lengthy, and results in an extensive package of information which the developer submits to PINS for examination. Examples of developer applications and examination documentations for recent offshore wind projects can be found on the PINS website [119].

Permitting timelines for the process are set out in legislation, requiring PINS to complete the examination process within 18 months of receiving all required information [120]. At the end of the period, PINS makes a recommendation to the BEIS Secretary of State, who has 3 months to decide. Generally, PINS' recommendations are accepted.

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

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45 Conditions can be wide ranging and include requirements on what type of infrastructure can be installed (for example specific turbine or foundation type), installation methods, where infrastructure should be placed, seasonal restrictions (for example carrying out specific activities outside of the migrating season of marine mammals or the breeding season of a given species), monitoring requirements, and emission limit values (such as noise, sediment dispersion, etc.).

The permitting process for offshore wind projects should also take into account the need for offshore cables and onshore infrastructure. For example, where a developer will be responsible for the export system to the onshore substation, it can be beneficial to consider the benefits of a single permitting process for all offshore and onshore elements of the project. Also important for onshore infrastructure are robust and proven processes relating to wayleave and compulsory purchase agreements.

A comparison of permitting processes in three offshore wind markets is presented in table 3.3.

TABLE 3.3: Comparison of permitting processes in the Netherlands, the UK (England and Wales) and the US

	1. Netherlands	2. UK (England and Wales)	3. US
Description	Process led by the Netherlands Enterprise Agency (RVO) prior to lease competition, then completed by developer once design finalized. Permitting of grid connection addressed separately, as grid connection delivered separately by the grid operator TenneT.	Process led by developer that prepares application once it has an agreement for lease and applies for permits via single permitting body. Covers all offshore and onshore permits, including relating to grid connection.	Process led by developer that prepares application once it has lease and engages with wide range of federal, state, and local bodies.
Permitting bodies	Ministry for Economic Affairs and Climate Policy issues permits.	PINS administers process, coordinating with all relevant stakeholders.	BOEM approves Site Assessment Plan (SAP) and Construction and Operation Plan (COP). Various federal agencies have to provide permits or be consulted, for example for generation, export system. These include Federal Energy Regulatory Commission (FERC) and National Oceanic and Atmospheric Administration (NOAA). Various state/local agencies provide permits or must be consulted, with electrical aspects the most complex; state/federal coordination efforts have been limited to date (except for Coastal Zone Management Act [CZMA]).

	1. Netherlands	2. UK (England and Wales)	3. US
Activities	**Government:** RVO completes preliminary application and submits all relevant documentation following surveys and consultation activities. **Government:** Ministry for Economic Affairs and Climate Policy makes preliminary decision. A project site will only be leased if preliminary permit awarded. **Developer:** Completes final application based on its late-stage wind farm design work. **Government:** Ministry for Economic Affairs and Climate Policy makes final decision.	**Developer:** Completes application and submits all relevant documentation, following surveys and consultation activities. **Permitting body:** Administers process: • Reviews application to ensure complete. • Examines application and coordinates responses from all stakeholders within an agreed timescale. • Makes recommendations to Secretary of State, including any conditions. **Government:** Department for Business, Energy and Industrial Strategy makes final decision based on recommendations.	**Developer:** Completes application and submits relevant documentation, following surveys and consultation activities. **Permitting bodies:** BOEM reviews, comments, and decides on SAP/COP completeness and prepares the Environmental Impact Statement (EIS), including stakeholder engagement, and uses this to inform its decision regarding approval of the COP; state and local agencies review power export system within their jurisdiction. **Federal government:** Makes final decision based on recommendations from BOEM regarding outer continental shelf (OCS) leases for the wind farm site. **State: Makes** final decisions regarding export system.
Pros/cons	**Pros:** Minimal permitting risk for developers. Process subject to strict time management, minimizing delays. Government has full control over location and is more in control of when projects get constructed. **Cons:** Upfront costs to government to undertake studies and plan project areas. Cost to maintain capability and resources within government. Developers are often better at selecting and designing sites, and at taking advantage of innovation that can lead to cost reductions.	**Pros:** Consistent and well documented process. Legislated timescales for examination, once all required information is received from project developer. Single main interface and defined timescales for recommending a decision. PINS can coordinate and plan activity relating to multiple projects and multiple stakeholders. Developer allowed to submit application for range of technical solutions to keep final design and procurement options open. **Cons:** As it is a general planning process for all infrastructure projects it is a bit separated from marine spatial planning (MSP)/ leasing. Does not deal so well with cumulative impacts/multiple offshore wind projects permitting at the same time.	**Pros:** BOEM has responsibility for leasing and permitting, enabling some synergies and continuity of communication. BOEM process is the same for each state. **Cons:** Complex process with variations depending on location, especially regarding export system. Range of stakeholders for developer to engage with.

Permitting Frameworks

A transparent and robust permitting framework is needed so all parties understand the process and assessment criteria. Any major infrastructure decision has parties with different opinions, so to protect all involved (including the environment), decisions need to be based on clear criteria. Examples of good practice in this area is the list of regulations presented by PINS in the UK [121] and BOEM in the US [109]. A clear process [120] helps stakeholder concerns to be addressed at an early stage. It also helps ensure that projects are built in a way that best meets the needs of all stakeholders.

Where policy commitments are in place relevant to offshore wind, it is important that there is a mechanism for these to be considered in permitting decisions. One example is renewable energy to facilitate carbon reduction. The permitting framework needs to provide guidance about how to balance such national commitments with local considerations.

Frameworks should allow for some flexibility in the "permitting envelope." Offshore wind technology continues to progress rapidly compared to project development timelines; often many years will elapse between starting a project's permitting process and reaching its financial close. It is important to allow projects to use the latest technology, as typically this helps reduce LCOE and environmental and social impacts. In the UK, the principle of Rochdale Envelope [122] provides the ability to permit a project without fixing every detail. The envelope encompasses ranges of technical characteristics such as the number of turbines, variations of rotor diameters and blade tip heights, and different foundation types. This means developers do not need to commit to specific technology choices early in a project's development, and thus will have flexibility to make those decisions often some years after applying for permits. There is also a benefit for permitting authorities, who require less time and resources to process requests for variations as technology and the supply chain evolves. Similarly, it is advantageous to incorporate a simplified process for assessing and approving minor changes after permits have been granted.

Frameworks should allow for a simplified approach to offshore wind project extensions. Project extensions (installing extra turbines next to an already operating wind farm) can be an efficient way to increase operating capacity. Permitting for any extensions should build on baseline survey results, original environmental impact assessments, what has already been learned about the impacts from the operating offshore wind farm, and must consider any potential cumulative environmental and social impacts of extending the original permit. This can reduce time and cost for the developer as well as for the permitting authorities' review of the extension project's permit applications.

Permitting frameworks are improved by including realistic but mandated timescales for determination. Up to 18 months has been shown as a realistic timescale, once all the necessary information has been submitted for determination (see for example Case Study 3.12).

Environmental and Social Impact Assessment (ESIA)

An ESIA is a review of the various possible environmental and social consequences of a new infrastructure project and their magnitudes. In established markets, all offshore wind projects require an ESIA as part of a developer's permit application. The completion of an ESIA is typically a fundamental requirement for most international lenders. Including a legal or regulatory requirement for ESIA to be carried out in accordance with GIIP would deliver significant benefits to offshore wind deployment. For example, see the World Bank's Environmental and Social Standards (ESS) [92] and the International Finance Corporation's Performance Standards (IFC PS) [123]. The benefits of this approach include:

- Increasing attractiveness of the market by providing regulatory certainty.
- Improving permitting processes by delivery of appropriate levels of environmental information.
- De-risking projects, as the ESIA is a useful risk identification and mitigation tool.

- Ensuring that projects are bankable, delivering ESIA will help projects to secure financing from multilateral institutions, which usually can only be accessed when the IFC PS, or equivalent, have been satisfied.

In countries where local ESIA requirements do not meet international standards, developers requiring international financing for projects will often need to produce two assessments: one to satisfy local authorities and another more comprehensive assessment to ensure that international standards are met. This has recently occurred for projects in Taiwan and Vietnam. By designing local ESIA requirements that are aligned with GIIP, developers will save substantial time and costs.

International Lending Requirements

Projects seeking international financing, or those seeking to voluntarily align with GIIP, will encounter environmental and social due diligence requirements in addition to ESIAs, to determine the sustainability of a development. For offshore wind developments, one of the main environmental risks associated with offshore wind development relates to impacts to biodiversity (e.g., impacts to seabirds and marine mammals). IFC PS6 represents leading practice in this respect, and the concepts and requirements are outlined in Case Study 3.11. Other international financial institutes (IFIs) often have the same or similar requirements. Ideally, the work required to align with international lending standards will inform the scope of the ESIA by identifying the highest priority environmental and social issues to consider, and will provide an indication of the type and nature of mitigation and offset measures a project may need to address. This is a useful early indication for project design and engineering, and for gauging the cost of and possible implementation partnerships for offsetting and conservation actions.

CASE STUDY 3.11: IFC Performance Standard 6—Biodiversity Conservation and Sustainable Management of Living Natural Resources

PS6 recognizes that protecting and conserving biodiversity, maintaining ecosystem services,[a] and sustainably managing living natural resources are fundamental to sustainable development. The supporting Guidance Note (GN) 6 [118] provides additional information on how the requirements of PS6 should be interpreted. The International Finance Corporation (IFC) PS6 is implemented by IFC's investment and advisory clients as a matter of compliance, but companies and lenders worldwide choose to align with the principles of IFC PS6 to demonstrate their commitment to good practice management of biodiversity.

PS6 defines three habitat types: modified, natural, and critical, distinguished based on the condition of that habitat. Critical habitats are defined as areas with a high biodiversity value. Critical habitats are a subset of modified and natural habitats; either can be critical habitat if the biodiversity present within them meets any of the five criteria[b] outlined in IFC PS6/GN6, and/or if they are wholly/partly within internationally or nationally recognized protected areas. IFC PS6 precludes development in the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Sites [124], and Alliance for Zero Extinction Sites [125].

Identifying Critical Habitat

Critical habitat assessment (CHA) is not an impact assessment process. The presence of critical habitat does not necessarily mean there is (or will be) an impact on critical habitat–qualifying biodiversity, but it does help to prioritize the most significant (potential) biodiversity risks. Critical habitat is determined on the basis of an ecologically coherent landscape or seascape unit that includes the project area of influence and may be relatively large. The intention is that developers identify project-related impacts, especially those on habitat connectivity, outside the boundaries of the project site (see GN6 para GN17).

PS6 Key Concepts

No net loss In natural habitats, PS6 requires no net loss (where feasible). No net loss is defined as the point at which project-related impacts on biodiversity are balanced by measures taken to avoid and minimize the project's impacts, to undertake on-site restoration, and finally, to offset significant residual impacts, if any, on an appropriate geographic scale (e.g., local, landscape level, national, regional).

Net gain For projects within critical habitats, PS6 requires net gain, irrespective of the potential for a residual project-related impact. Net gains are defined as additional conservation outcomes that can be achieved for the biodiversity values for which the critical habitat was designated.

Net gain is achieved through offsets. Although often potentially, or conceptually feasible, net gain is complex and challenging in practice. It can be expensive, and the outcomes are often uncertain. Hence, it is crucially important to ensure residual impacts are as low as practically possible through effective application of the mitigation hierarchy (avoidance, minimization, restoration, and offsetting).

Offsetting is a measure of last resort to address residual impacts on biodiversity after all the other components of the mitigation hierarchy have been fully applied. In general, offsets require a high standard of evidence to demonstrate no net loss or net gain, convincingly, which means effective engagement with the relevant stakeholders is essential. Monitoring programs need to be carefully designed to track the scale of impacts and the effectiveness of offsets for target features.

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a. Ecosystem services are often underpinned by biodiversity, and therefore biodiversity impacts can adversely affect the delivery of ecosystem services.

b. The five criteria for critical habitat outlined in IFC PS6/GN6 include:

- Criterion 1: Critically endangered (CR) and/or endangered (EN) species;
- Criterion 2: Endemic or restricted-range species;
- Criterion 3: Migratory or congregatory species;
- Criterion 4: Highly threatened and/or unique ecosystems; and
- Criterion 5: Key evolutionary processes.

Baseline Studies

Baseline surveys provide quantifiable data for ESIA, and for residual impact assessment and mitigation planning. Developers are responsible for surveys at a project level but, as mentioned in section 2.5, governments can proactively commission regional-scale baseline studies that inform strategic planning and can also support project ESIAs. Iterative rounds of surveys are likely to be required to properly assess and mitigate risk. It is essential that baseline surveys are robust and comprehensive because they underpin the project's approach to environmental and social management, and they support effective communication with stakeholders. Baseline surveys need to be detailed, especially for high-risk species and at the appropriate spatial scale to address all the potential direct, indirect, and cumulative impacts of a project. They also need to cover multiple seasons to properly understand how the baseline changes through the year.[46] It is important to involve specific key stakeholders (such as biodiversity specialists and the project engineering team) in baseline survey design. BOEM has published a series of guidelines [126] for environmental, social, and physical surveys for offshore wind development, and these guidelines could help inform survey design in emerging markets.

Governments should ensure that developers conduct project-level baseline surveys to cover multiple seasons and/or annual cycles (e.g., at least two migratory periods). This is to properly understand ecological

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46 Comprehensive baseline surveys are likely to be required for birds, bats, fish, marine mammals, sea turtles and natural habitats.

requirements, changes in species population and distribution, behavioral cycles, and key points in species life history. Comprehensive baseline surveys are likely to be required for the following biodiversity values:

- Species: Birds, bats, fish, marine mammals, and sea turtles
- Natural habitats

Stakeholder Engagement

During the permitting process, stakeholder engagement and public consultation are vital to identify and address concerns. Good management of environmental issues, through ESIA, requires public participation. Local communities can provide additional information which can help reduce the risks of developing an offshore wind project. In particular, input from marginalized communities and indigenous people is important to gain the social license to operate, even where a permit is granted. This is because, while wind power is often welcomed by the public on a national level, any negative local impacts of a specific project are often perceived to outweigh the benefits [127]. To illustrate this point, Case Study 3.12 describes how the Cape Wind project in the US was ultimately abandoned due to public resistance [128] and goes on to discuss Vineyard Wind that has had a more positive permitting experience.

CASE STUDY 3.12: US Cape Wind and Vineyard Wind Projects

A planned 420 MW wind farm in the US with 130 turbines was ultimately abandoned due to protracted resistance, including multiple legal challenges [129]. Cape Wind faced local resistance, supplemented by significant high-profile individuals such as Sen. Edward Kennedy and William Koch who contributed at least US$1.5 million to campaigns opposing the development [130]. Failure occurred despite firm financial contracts and improved energy provision to the isolated island inhabitants who pay above-average energy bills due to imported energy. The project was conceived and developed before government frameworks for offshore wind had been established, and so the site was selected by the developer with limited stakeholder engagement.

In 2021, the permitting process for Vineyard Wind, the US's first industry-scale offshore wind farm was completed. Local stakeholders had been engaged and were supportive of this project [131]. Importantly the Vineyard Wind project was located within the Bureau of Ocean Energy Management (BOEM) federal lease site where a constraint analysis had been undertaken. This shows the importance of undertaking early marine spatial planning (MSP) and ensuring influential stakeholders and locals are on board with the proposed project to prevent extreme resistance halting the progression of any wind farms. This is of particular importance for early wind farm projects where a local track record is not available to reassure these stakeholders. The Federal Infrastructure Permitting Dashboard [132] is a good example of government ensuring good communication about permitting activities.

Good quality ESIA coupled with public consultation can help reduce local objections. Local stakeholder groups such as commercial or artisanal[47] fisheries should be consulted as part of the permitting process. Providing a representative for a group of local individuals, or giving another form of support, will help improve the efficiency of the consultation process. An overview of the minimum key stakeholders the developer is required to contact for input should be defined clearly by the government (or delegated permitting approval body), as shown in figure 3.8. Any centrally developed list will not be exhaustive, and it should be made clear that the developer should develop their own site-specific stakeholder engagement plan and conduct adequate engagement to satisfy the permitting body.

47 Artisanal fisheries refer to various small-scale, low-technology, low-capital fishing practices undertaken by individual fishing households (as opposed to companies).

FIGURE 3.8: Stakeholders for developers to engage with during permitting

R Responsible A Accountable C Consulted I Informed

Government	R	May help with educating/resourcing stakeholders.
Department of Energy	R	Integral for grid integration and OFTO. May review permit applications.
Marine Department	C	Consult on any impacts for proposed siting/construction/operation.
Environmental Department	C	Help define input required for ESIA. May review some or all of application.
Planning Department	A	One or multiple bodies to review and approve application(s), as defined in strategy.
Industry/Business Department	C	Views on imported skills/workforce. May be able to help set up local supply chains. Health and safety.
Treasury	I	Inform to help with future strategic work or investment.
Aviation	C	Developer to consult to confirm flight paths and other impacts are acceptable.
Ministry of Defense	C	Developer to consult to confirm impacts are acceptable.
Marine Users	C	Developer to consult with marine users such as shipping and commercial fisheries for marine impacts or agreements required.
Local Authorities	R A	Consult for key input into strategy. May review application or in some instances make permitting decisions if delegated to by government.
Grid Owners	R	May be responsible for grid connection. Key for project program. Consult for approval.
Infrastructure Owners	C	Developer to consult for local infrastructure impacts or agreements required.
Certification Bodies	C	Developer to consult to prepare for technical sign off.
Public	I	Developer/government are likely to inform about progress.
Local Residents	C	Developer to consult to confirm views. May be a key stakeholder and provide much input.
Conservation Groups	C	Developer to consult to confirm environmental impacts are acceptable for relevant conservation areas.

Note: ESIA = environmental and social impact assessment; H&S = health and safety; OFTO = offshore transmission owner.

Local stakeholder organizations at a project-specific level also need to be well informed and well resourced. To achieve this, governments can develop a formal consortium to support fragmented stakeholders. Experience in established markets has shown it is important to have well-resourced, well-informed consultees in order that rational decisions are made in reasonable timescales. See Case Study 3.13, for early lessons from the UK on consultee resources during permitting that are also likely to be relevant in emerging offshore wind markets.

CASE STUDY 3.13: UK Permitting: The Value of Well-Resourced Consultees

In the early years in the UK, many statutory consultees were often too busy managing their normal workload and were neither educated nor resourced well enough to assess offshore wind applications, which raised new questions for them to address. The volume of applications and the work required led to delays in processing applications and, in some cases, negative decisions made according to the precautionary principle[a] due to lack of experience, evidence, and time available.

To alleviate the issue, The Crown Estate funded six roles in consultees to resource processing of Leasing Round 3 project applications. In time, stakeholders gained knowledge, and processes were put in place to give early warning of applications and to plan and manage the assessment, leading in most cases to efficient, timely assessment and rational outcomes.

a. The precautionary principle is that until there is strong evidence that an activity does not cause harm, then that activity should be limited until there is such evidence.

Local communities need to see benefits from projects. To secure and maintain public acceptance, developers need to create a combination of social, economic, and environmental benefits beyond the value to national or regional clean energy agendas. There is no single approach to designing and implementing local benefit-sharing initiatives, but lessons from others' experiences offer robust guidance [133].

KEY SUCCESS FACTORS

Related to permitting for offshore wind, governments should:

a. Establish a transparent, robust, and flexible permitting process.
b. Ensure that the organization administering permitting is trusted and well resourced.
c. Define requirements for environmental and social impact assessments, following good international practice, including for robust baseline studies.
d. Support broad stakeholder engagement and education about offshore wind.

Suggested reading materials are found in appendix A and full references found in appendix B.

3.6 Offtake and Revenue

Offshore wind projects are typically designed to operate for at least 25 years. To recoup their investments, developers, lenders and investors desire long-term visibility and certainty of the revenues a project will generate. Similar to other renewable energy projects, revenue certainty can be provided by long-term offtake agreements[48] (PPAs) and/or government mechanisms to provide revenue support.

Emerging Market Context

Established offshore wind markets, such as those in northern Europe, typically have wholesale electricity markets.[49] In these countries, the revenue support mechanisms have been designed to give developers[50] a known and guaranteed power purchase price, typically for a period of 15 to 20 years. Developers value the revenue stabilization[51] provided by governments, as it helps them manage revenue risk and reduce LCOE.

Many emerging markets do not have liberalized electricity markets, and typically the state-owned utility will be the sole offtaker, typically under long term contracts, for power projects developed and owned by IPPs. In these cases, there is no wholesale electricity market and the seller will enter into a long-term Power Purchase Agreement (PPA) with the offtaker at a set tariff. If there are issues with the creditworthiness of the offtaker, the seller (and its lenders) will often seek government support to backstop any risk associated with offtaker liquidity and ability to pay.

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48 Offtake agreements can take several forms, including Power Purchase Agreements (PPA), Feed-In Tariffs (FIT), Contracts for Difference (CFD) and bilateral agreements with corporate entities

49 Wholesale electricity markets are those that "allow the buying and selling of power between generators and resellers. Resellers include electricity utility companies, competitive power providers and electricity marketers." (source: www.pjm.com) Competitive wholesale markets are a key feature of liberalized electricity markets where generation, transmission and distribution have been unbundled.

50 In this section, for consistency throughout this report, the term "developer" is used interchangeably with independent power producer (IPP), generator, or seller, and refers to the entity entering into an offshore wind offtake agreement.

51 Revenue stabilization gives project owners a fixed or minimum (floor) payment per megawatt hour (MWh), isolated from any variation in instantaneous market price for electricity. In principle, project owners are willing to accept a lower fixed payment per MWh than the average they would anticipate receiving from the market, to reduce merchant risk.

To establish a new offshore wind market, governments will often need to provide a higher level of revenue support, or subsidy, to cover the tariff cost premium for the first projects. The first offshore wind projects in emerging markets will typically have an LCOE that is higher than the tariffs paid for onshore renewables and conventional generation. However, as previously discussed in section 2.3, the LCOE of offshore wind can be expected to fall with subsequent projects. The price level of this revenue support can be set by governments or, if sufficient competition exists, by the market through a competitive process. In some established and developed offshore wind markets, offshore wind projects are bidding at prices that are lower than the wholesale market price. In the UK's most recent offshore wind auction, for example, winning bids (~US$55/MWh) were lower than the predicted average wholesale electricity price (~US$70/MWh) [134].

The starting point for any country considering revenue support and offtake agreements for offshore wind should be to review the suitability of what it has used for other forms of variable renewables. In some cases, existing procurement mechanisms can be adapted to offshore wind as long as these mechanisms reflect the critical differences between offshore wind and conventional renewables (e.g. onshore wind and solar). For example, the relatively higher risks and CAPEX of offshore wind will usually require a project finance structure supported by international lenders with stringent requirements, thus increasing the need for offtake agreements that adhere to international standards of bankability.

Types of Offtake Agreements

Several types of offtake mechanisms have been used in established offshore wind markets. The following points provide brief summaries of the main mechanisms, and examples of their use in a range of markets are provided in figure 3.9.

- **Feed-in tariff (FIT):** Here, a government sets a fixed power price and pays for electricity produced over all or a majority of the anticipated project life. Usually, a government progressively lowers the tariff offered to new projects as the market matures. This drives cost reductions and lowers the costs to consumers and taxpayers.[52] Germany was an early pioneer of FITs for renewables. While the approach did lower costs, it did not necessarily allow for full price discovery as developers simply reduced costs to an amount needed to pass their internal rate of return (IRR) hurdle rate.
- **Renewable energy certificate (REC):** As a supplement to a separate offtake agreement, a government awards certificates for renewable energy generation and requires that electricity generating companies, or electricity suppliers, provide certificates covering a growing percentage of their total power volume through a renewable portfolio standard (RPS)[53] or similar certificate. Generating companies can obtain enough certificates either by generating using renewables, by buying certificates from others that have generated using renewables, or by paying an increasing buyout charge to the government. While successful in driving volume and having an element of price discovery (the price being set by willingness to pay, rather than being defined by government), it does not facilitate direct competition driving such price discovery.
- **Feed-in premium:** Similar to FIT, but the government pays a premium above the wholesale price. Denmark uses this for "open door" projects (see [101]). The developer will receive a varying revenue from the sale of generated electricity. This type of scheme is only relevant where there is a wholesale electricity market.
- **Contract for Difference (CfD):**[54] Sometimes known as a sliding feed-in premium. A government awards a contract for a strike price, which ensures a developer will receive at least that price for electricity generated over the length, or a majority of, a project's life. There are two main forms:
  - In a one-way CfD, when the wholesale price is lower than the CfD's strike price, the contract provides a top-up payment to the developer, equal to the difference between the wholesale electricity price and

52 The tariff is set in law (which therefore carries a risk of change in legislation, as seen for onshore renewables in Spain in 2014).

53 The RPS is a policy tool to expand production of renewable-generated electricity to reflect what its role would be if long-run social costs instead of short-run financial costs were the determinant of electricity generation investment [325].

54 A CfD is a bilateral contract with the government (or government-backed counterparty), which therefore cannot be changed by legislation, protecting the investor from legislation risk.

the strike price. Sometimes there is a maximum top up to limit consumer cost when wholesale prices are low. A one-way CfD based on a strike price of zero means that the plant effectively operates as a merchant power plant.

- In a two-way CfD, the one-way CfD mechanism applies, but the developer pays money back to the government if the wholesale electricity price is higher than the strike price. Although the developer cannot benefit from the high wholesale electricity prices, it nonetheless has the certainty of always receiving the strike price while the government has an opportunity to share in the upside. As with feed-in premiums, CfDs are only relevant where there is a wholesale electricity market.

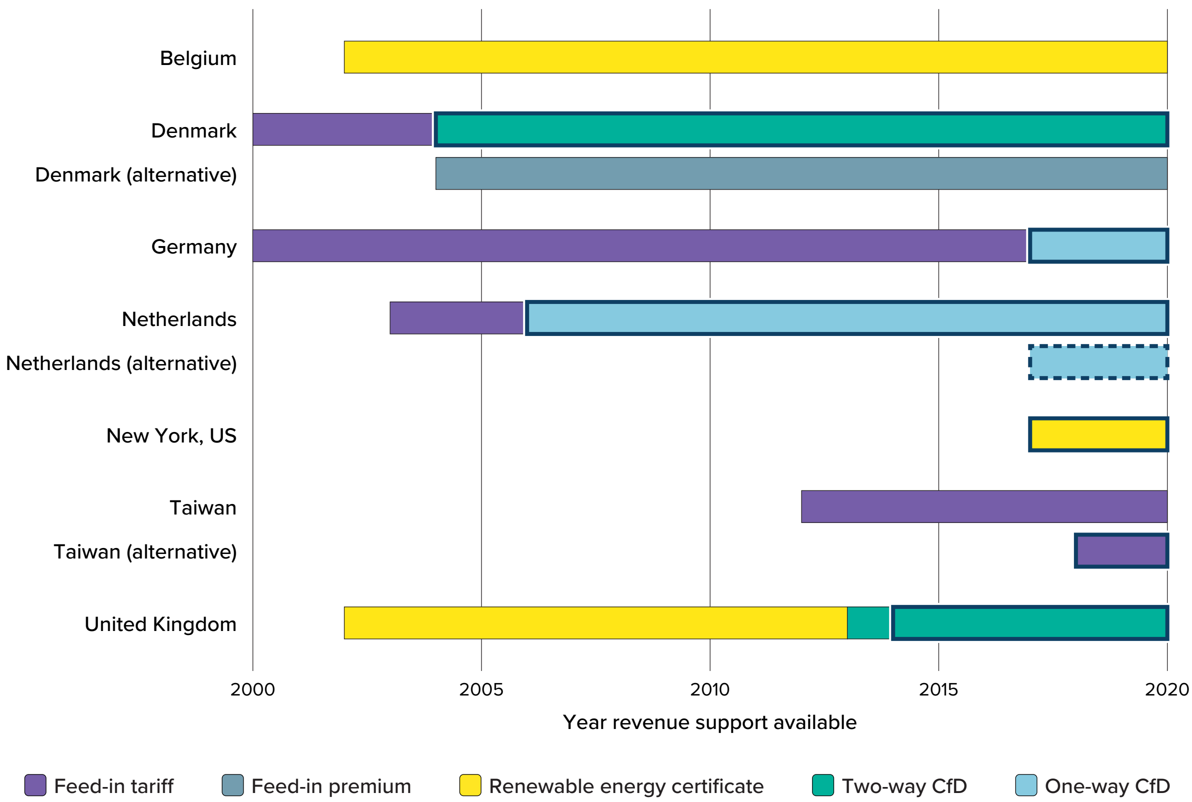
- In each case, there is a known gap between the wholesale price and the cost of offshore wind. Clear identification of this price difference affords an ability to clearly quantify the long-term incremental cost of offshore wind. This is not necessarily the case in non-liberalized markets.

Fiscal Support

Incentives can also be in the form of fiscal (typically tax) incentives [135]. In the US, production tax credits (PTCs) have been used to support market growth. PTCs provide developers with a tax rebate proportional to the electricity generated.

Although not associated with generation output, fiscal support can include generic incentives that apply across many industries and those specific to renewables or offshore wind. For example, the wind industry has benefitted in France and the Netherlands from accelerated depreciation on capital investment, and in many European countries through exemptions from capital gains tax on the sale of shares in project companies. Similarly, in emerging markets, there is precedence of governments providing financial incentives, such as tax benefits, for power projects; similar incentives could be applied for offshore wind industry.

FIGURE 3.9: Evolution of financial revenue support systems in a range of markets



Note: Thick blue border indicates systems with competition based on price; dashed indicates zero value bids and competition based on other criteria.

Processes for Awarding Offtake Agreements

When designing the process to award offtake agreements, policymakers need to answer three main questions:

1. At what stage of project development will agreements be awarded and by what mechanism?
2. What kind of offtake agreement or revenue support mechanism will be offered?
3. What should the offtake price be and how to cover the cost difference between the price of offshore wind power and the marginal system price?

Offtake agreements can be awarded at different points in the project development cycle (see figure 3.3). In established markets awards have tended to be at one of two points:

- With lease, combined into a single award, after the government has carried out early-stage project development work (the one-competition model).
- Separately, after leasing and permitting and as the last activity before a project reaches the final investment decision (FID) (the two-competition model).

At these points, the level of support can either be set by government or through a competitive auction process.

- If set by government, the government typically decides who receives support by an administrative process that considers the capability of competing developers to deliver projects within a given timescale and the wider benefits each project would bring.
- If set by competitive auction, then the winning bidders with the lowest price receive support.

Industry confidence in a robust, transparent, and fair process to award revenue support is key. Governments can enable this through appointing a trusted and well-resourced organization to administer revenue support and ensuring strong processes are in place. Key considerations are similar to those discussed for leases in section 3.4.

There should be a moderate oversupply of bidders seeking revenue support. This will drive competition and allow for some attrition, as some projects may fail at some point during development or the final capacity may be lower than initially planned due to technical and permitting constraints.

The process should ensure successful development. Typically, a selection process will have prequalification criteria to ensure that any project developer receiving an award has the capability to deliver the project.

Transitions between revenue support agreements need to be carefully managed. As for other frameworks, changes often require significant time to enable consultation and changes in primary legislation. An example of this transition being well led is provided in Case Study 3.14.

CASE STUDY 3.14: UK's Final Investment Decision Enabling for Renewables Program

The UK government used the Final Investment Decision Enabling for Renewables (FIDER) program in 2013 [136] to provide continuity for the offshore wind industry during the transition from renewable energy certificates (RECs) to auctioned Contracts for Difference (CfDs) as part of its process of Electricity Market Reform (EMR) [137].

This transition took two to three years, and the interim solution, a simplified competition process with a strike price set by government for a subset of suitable projects, enabled ongoing activity and investment, avoiding gaps in wind farm development and installation activity. Notably, the UK also benefitted from the presence of an established wholesale electricity market that allowed parties to monitor merchant price risk over time.

The downside of this process was that the FIDER strike prices turned out to be overly generous to project developers due to the rapidly falling levelized cost of energy (LCOE) at the time. Governments setting strike prices (or feed-in tariffs [FITs]) should seek to address this point.

To accelerate the market, some governments have considered negotiating revenue support contracts bilaterally with developers of early projects. If a government does decide to bilaterally negotiate revenue support, it is essential that the process is as fair and transparent as possible. Direct negotiation is more prone to corruption and nepotism, and therefore more likely to be challenged by future political administrations. It also risks impacting competition and sending bad market signals.

Transition to Auctions

The introduction of competitive auctions has transformed the cost of offshore wind by driving direct competition throughout the supply chain. The impact surprised many within the industry. Due to the good visibility of large-scale markets in established countries, industry was prepared to accelerate technology development, invest in improved manufacturing and installation methods, and find improved ways to collaborate to reduce cost of energy significantly over time. See Case Study 3.15.

CASE STUDY 3.15: Impact of Auctions

The introduction of auctions has transformed the cost of offshore wind. In 2011 the levelized cost of energy (LCOE) of an offshore wind project was up to US$230/MWh, and the industry had reached a crossroads. There was a large pipeline of projects in Germany and the UK, and governments were cautious about supporting these projects at this cost.

The first country to introduce auctions was the UK. For the first time, developers were required to compete for price support. The first auction in 2015 supported two projects at prices between US$150–170/MWh (at 2012 prices). Subsequent auctions in Denmark, Germany, the Netherlands, and the UK have achieved successively lower prices. Projects reaching final investment decision (FID) in 2020 had auction prices equivalent to LCOE less than US$60/MWh. Innovation in the supply chain has been a key part of this change, but it has been driven by the need to compete at lower prices.

The auction process varies between countries. In Denmark and the Netherlands, developers all bid for the same site. In the UK and the US, developers develop sites, then bid their projects into auctions. There are advantages of both approaches, but the most important aspect is that auctions force developers to compete. Auctions have been the main driver for cost reduction, promoting efficiency and learning, innovation, and lowering risk and margins.

Revenue support competitions offer a key opportunity to ensure that wider policy objectives are met. As discussed in Case Study 3.16, New York has directly combined both price and local economic benefit aspects in the same auction. The UK applies a gate approach, such that only bidders showing well-documented intent regarding wider benefits are able to bid.

CASE STUDY 3.16: New York State Local Economic Benefit

In its 2019 and 2020 solicitations (revenue support auctions) [138], New York state has balanced cost to consumers and local supply chain development. In its latest competition, it awarded bidders 70 percent of marks for their per MWh price, 10 percent for viability (i.e., the likelihood that the project will be successful), and 20 percent for local economic benefits offered.

In response to the latest competition, the winning bidder offered to establish in-state facilities for the manufacturing of foundation components and towers, and port facilities for construction and operation.

Examples of revenue support resulting from different process and policy decisions are compared in table 3.4.

TABLE 3.4: Comparison of competitive processes to award revenue support in the Netherlands, the UK, and the US

	1. Netherlands	2. United Kingdom	3. US (New York)
Description	Auction for a sliding feed-in premium (CfD) combined with leasing round once early project design and permitting completed by government. Grid connection addressed separately.	CfD auction. Fixed foundation offshore wind projects compete for CfDs within a discrete "pot." Bids are required under ceiling prices set by government. Floating wind is proposed to be in another grouping, competing with less established technologies.	State-level auction including combined assessment of price and local benefit. Auction is for the price of Offshore Renewable Energy Certificates (ORECs) scheme. Two schemes are available: • Fixed OREC: effectively projects that receive a fixed, premium price in addition to their revenues from selling to the market. • Index OREC: effectively a two-sided CfD that provides a total remuneration price level and more certainty on revenues.
Managing organization(s)	Process led by the Netherlands Enterprise Agency (RVO).	Government Department for Business, Energy and Industrial Strategy (BEIS) National Grid ESO runs the CfD allocation process.	New York State Energy Research and Development Authority (NYSERDA).
Activities	**Developer:** Provides bid document including design, delivery, social considerations. **Government:** Runs prequalification process to ensure developers have the required technical and financial capability. Bids are evaluated on price (not relevant if zero subsidy), capability, experience, project design, and measures to assure cost efficiency.	**Developer:** Must previously have secured lease, permits, and grid connection, and have supply chain plan approved by government (describing intent and commitments regarding wider benefits of project and its work in offshore wind, with local focus). Submits delivery plan and sealed £/MWh bid for given delivery year (start of operation). **Government:** Approves and announces auction results. National Grid ESO assesses and allocates bids, keeping budget below auction allocation.	**Developer:** Must previously have lease at federal level. Provides significant bid document covering design, delivery, local economic benefit, and US$/MWh bid, with a range of options. **NYSERDA:** Assesses bids and selects winner(s) to award support agreements.

	1. Netherlands	2. United Kingdom	3. US (New York)
Pros/cons (see also pros and cons of one- and two-competition models in Figure 3.3)	**Pros:** Direct competition between developers for same project. **Cons:** No price competition when zero-subsidy bids. No price stabilization to reduce developer revenue risk when zero-subsidy bids.	**Pros:** Competition between projects, now for access to price stabilization at minimal cost to government. **Cons:** Developers carry significant spend and risk up to award. Indirect treatment of local economic benefit does not give industry clarity.	**Pros:** Clear understanding of evaluation criteria between cost (70%), local economic benefit (20%), and viability (10%). **Cons:** Potential disconnect between states and federal government.
Further information	See [104] [139]	See [140] [141]	See [138] [142]

Governments need to be careful about how auctions are introduced in emerging markets. Auctions have worked well in markets with industry confidence of mid-term volume and full price transparency. The risks to auctions in emerging markets are:

- Too few bidders, due to unattractive auction conditions.
- Too many/inexperienced bidders, leading to delays, uncertainty and a likelihood of unsustainably low winning bids. China learned from this experience in the early stages of its offshore wind markets—see Case Study 3.17

CASE STUDY 3.17: The Evolution of China's Offshore Wind Market

China has a thriving offshore wind industry, but it has evolved independently and with little collaboration with other markets. In 2007 a single turbine was demonstrated offshore, connected to an offshore oil platform in Bohai. China's first commercial project, the 102 MW Donghai Bridge, began operating in 2010. In the decade since, China has deployed over 10 GW of offshore wind and is now the largest offshore wind market in the world. Its market has developed in four main phases:

- **Demonstration** (2007–2010) Initial pilot projects to prove the technology. Tariffs and support were negotiated bilaterally between developers and the government [143].
- **Concession** (2010–2014) A competition selected four state-owned enterprises (SOE)s to deliver China's first large scale-projects. The projects were delayed for seven years because the bidding prices were too low [144]. This is a relevant example of poor competition design leading to an unsuccessful outcome.
- **Feed-in-tariff** (2014–2021) Government-set feed-in-tariffs (FITs) were introduced, and projects in the intertidal and offshore zones were offered tariffs of CNY 750 and CNY 850/MWh (US$115 and US$131/MWh), respectively, for 20 years. Project sites were planned and approved at a provincial level.
- **Market competition** (2019–onward) Provinces ran auctions for offshore wind tariffs, with the first auction in 2019 resulting in CNY 0.62/kWh (US$96/MWh) [145]. Tariff price accounted for 40 percent of the total evaluation score, with evaluation also including bidders' financial strength and project technical plans [146].

China is currently experiencing a surge in installations as the FIT scheme, which offers a comparatively higher price and easier route for developers, ends for new projects at the end of 2021. Developers and installers are rushing to get projects operational before the end of 2021; however, a shortage of installation vessels is limiting progress [147].

Despite the extensive experience, China's unique market conditions, with a high level of state involvement in all aspects of offshore wind development, means that only some lessons from China are transferrable and relevant to other emerging markets. Some Chinese firms are active in international offshore wind markets but, to date, there has been little export from China.

Experience in established markets has shown that industry consultation during the design of auctions helps to create acceptable conditions and maximize the chance of a successful outcome. Case Study 3.18 provides an example from Turkey, where unattractive auction conditions led to no bids being submitted in the country's first offshore wind auction.

CASE STUDY 3.18: Turkey's First Offshore Wind Auction

Turkey's first offshore wind auction in 2018 identified specific sites, but it set a relatively low ceiling (maximum bid) price, included local content requirements, and did not provide adequate site characterization data (e.g., wind, metocean, seabed) which developers require to form a competitive bid. Furthermore, at the time of bidding, there was little visibility of future offshore wind specific targets or subsequent auction rounds.

As a result, no bids were submitted. Turkey is now working with the World Bank Group and others to establish an offshore wind roadmap, giving clarity on the industry's long-term development and building on the lessons learned from the first auction.

Bankability of Offtake Agreements

To date, most offshore wind offtake agreements have been in countries with liberalized electricity sectors and private buyers of electricity. Agreements have therefore focused on the sale and purchase of electricity but with limited obligations on construction and commissioning, and limited protection for matters such as a change in law.

Taiwan is one of the few cases where offtake agreements have been arranged in a country without a liberalized electricity market. Here developers and lenders have been concerned over the bankability of the nonnegotiable, short-form PPAs offered by the state-owned utility, Taipower. The industry has now become sufficiently comfortable with these PPAs through a better understanding of the offtaker, the predictability of the underlying electricity system, and more general macroeconomic fundamentals.

To provide access to international finance at an attractive cost, it is critical that the offtake agreement is considered bankable for that market. Given limited or no real comparable precedents, the commercial PPA structure for offshore wind in liberalized markets is likely to be of limited value when structuring offtake arrangements for offshore wind in emerging markets. Instead, the offtake agreement provided by a state-owned or major utility offtaker is likely to be developed from the equivalent form of a PPA for onshore wind in that market and/or region.

Offtake agreements are typically structured to provide some flexibility in line with the nature of offshore wind construction. Projects are usually given commissioning windows rather than specific commissioning dates and, in case of delay, the projects risk a reduction in the revenue support period rather than liquidated damages. Given the size of projects, offshore wind turbines often commence operation in "tranches" as different parts of a project become operational, and benefit from a specific mechanism for payment prior to the full operation of the project (early generation revenues). In offshore wind, early generation revenues can play a substantial role in ensuring the viability of the financing structure.

Further examples, focused on onshore renewables, are provided by the US International Development Finance Corporation [148]. An existing offshore wind power purchase agreement [149] can provide a useful starting point for consideration.

CASE STUDY 3.19: Bankability of Offtake Agreements

It is critical for offshore wind developers that offtake agreements provide a bankable revenue stream. This relates to certainty of the offtake contract terms and the robustness of the contracting organization, as well as a fixed revenue per MWh.

For (limited recourse) wind project finance, the following elements should be reflected in the PPA (adapted from "10 Important Features to Include or Consider for a Bankable PPA", OPIC/International Trade Administration/USAID/USTDA):

1. *Dispatch risk.* Offtake should be on a Take and Pay basis whereby the Seller is paid for all energy produced; in the event that energy cannot be dispatched to the grid (that is, curtailed) then the Seller is paid "Deemed Energy" based on what would have been delivered.
2. *Fixed tariff.* The tariff should be a fixed amount that can cover the project's operation, debt repayments and provide a reasonable return on equity. The tariff may be partially or fully indexed.
3. *Foreign exchange.* Currency can represent a substantial risk to the project; as such, the PPA should either be in foreign currency or linked to a hard currency exchange rate. There should also be no limitations on the transfer of funds to offshore accounts as needed.
4. *Change in law protection.* The PPA needs to clearly allocate risk stemming from a change in law or tax law that impacts a project's revenues. Lenders will typically require this risk to be borne by the offtaker.
5. *Force Majeure.* The seller should be excused from performing its obligations if a force majeure event prevents such performance. The allocation of costs and risk of loss associated with a force majeure event will depend on the availability of insurance and in some cases the degree of political risk in the country/region. Typical protections could include Performance Relief, Economic Relief and Termination Protections/Compensation.
6. *Dispute resolution.* In the event of disagreement between the parties, the dispute should be referred to a neutral jurisdiction with generally accepted international rules (e.g. International Criminal Court).
7. *Termination protection.* The PPA needs to clearly specify the conditions under which either party may terminate the agreement. In the event that the project is transferred to the offtaker, then the offtaker needs to provide a payment at least equal to the outstanding debt and (in the case of offtaker default) a reasonable return on equity.
8. *Assignment and step-in rights.* Lenders may require the ability to step into the position of a borrower in specific circumstances. An early agreement with the borrower on the major project contracts is important, noting where lenders have a legitimate need to step in.
9. *Offtaker support.* In cases where the offtaker's creditworthiness is in question, there may be a need for backstop of payment obligations in the form of a sovereign guarantee or other liquidity support
10. *Interconnection risk.* The PPA should consider what happens when the plant is ready to generate before the transmission line is complete. In these cases there may be provisions for "Deemed Commissioning"

Future Options for Power Offtake

Projects in established markets with high wind speeds are on the cusp of selling power without revenue support, through securing a sequence of Corporate Power Purchase Agreements (CPPAs). As the benefit of government-provided price support is reduced through competition, project developers are seeking other revenue options, including CPPAs. A benefit to governments is that CPPAs transfer more risk and spend into the private sector (as has been enabled in Taiwan [150]). The uptake of CPPAs can introduce new challenges; for example, in the UK, the government uses the revenue support auction to encourage developer supply chain choices to increase local economic benefits. If project developers bypass this auction, then the government loses this opportunity. The latest arrangements in Taiwan require those seeking CPPAs to also win a zero-value contract in the government auction, thereby enabling the government to keep imposing local content requirements. As costs reduce, governments should look at introducing rules to allow corporate PPAs as an option for project developers.

As more confidence is gained in the offshore wind industry, CPPAs are being set up in advance of project construction. For example, Ørsted has already signed two CPPAs for a total of 350 MW output of the 900 MW Borkum Riffgrund 3 wind farm in Germany that is due to come online in 2025 [151]. It is unlikely, however, that CPPAs will be able to completely replace the government revenue support model without impacting the ability of countries to meet their offshore wind targets. This is because, in most cases, corporate offtakers cannot take very large volumes of energy and cannot enter into CPPAs for tenors that are as long as the CfD/FiT typically offered by governments. In addition, CPPAs are only viable where there is a sufficient pool of creditworthy corporate offtakers.

As the global energy transition continues, offshore wind will be used in the production of green hydrogen[55] and other products such as green ammonia for use in industry and transportation. In established markets, there are already over 20 GW of offshore wind projects planned to produce green hydrogen.[56] These are mostly intended to supply industrial activities with an existing hydrogen demand. For example, Ørsted's planned SeaH2Land project [152] is intended to be operational by 2030 and comprises a 2 GW offshore wind generation with a 1 GW electrolyzer capacity. The project would supply industrial demand in the Netherlands and Belgium, displacing the existing high demand for hydrogen which is derived from fossil fuels. The green hydrogen offtake agreement could also help diversify the offtaker risk, providing some flexibility in the sale of power. Projects are now being proposed in emerging markets such as Brazil [153] [154] and Vietnam [155].

The use of power for green hydrogen production can enable an increased scale of offshore wind generation, and therefore lower the cost of energy. This could be especially relevant for markets where local electricity demands may only require a small supply of offshore wind, or where grid availability is limited. This would enable a smaller emerging market to reduce offshore wind LCOE, help decarbonize local industry, and generate a new income stream for the country through the export of green hydrogen.

Emerging markets could benefit from the development of local supply chains for green hydrogen. The cost of producing green hydrogen needs to reduce substantially to allow it to be competitive with other forms of hydrogen. Some cost reductions could come from manufacturing the equipment, such as hydrolyzers, in emerging markets. This could provide new industrial opportunities, the creation of jobs, and economic benefits.

55 Hydrogen produced using electricity from renewable sources, such as offshore wind, is sometimes known as renewable or green hydrogen.

56 The production of green hydrogen is not yet commercially mature and current costs are high. However, costs are expected to fall rapidly over the coming decade as the technology advances and projects are deployed at increasing scale. Emerging markets should, therefore, consider green hydrogen production from offshore wind as part of a mid- to long-term decarbonization strategy.

KEY SUCCESS FACTORS

Related to revenue support for offshore wind, governments should:

a. Structure offtake agreement processes to be robust, transparent, and fair.
b. Ensure the offtake agreement is bankable and provides investors with the certainty needed.
c. Enable price competition when awarding offtake agreements to drive cost reduction and a sustainable market.

Suggested reading materials are found in appendix A and full references found in appendix B.

3.7 Export System and Grid Connection

Enabling timely connection to the transmission network is crucial for each offshore wind project.

Timely Connection

Governments play an important role in ensuring a timely and cost-effective offshore export system to connect into the national transmission network. This requires the construction of an offshore export system comprising offshore substation(s) (if far enough from shore for these to be required), export cables, and connection onshore at a substation meeting the national network as shown in figure 3.10. Providing enough capacity at the right time requires careful, long-term management and sufficient resources from within the transmission network operator. For details of the wider transmission network capacity planning and transmission network update considerations, see section 4.4.

Timing should be aligned with policy targets for deployment to allow industry to prepare accordingly. There was a time in Germany where several offshore wind projects could not export power after they were completed because the export connection was incomplete. Such events, which impacted Nordsee Ost wind farm [156], are expensive and affect industry confidence. Export systems can have the longest lead time of any aspect of an offshore wind project.

Developers require a clear, bankable, framework to apply for a grid connection. It can take many years before a connection to the transmission network is available, as this can involve local or wider upgrades, depending on the capacity the developer seeks to connect and the strength of the local transmission network. A robust, fair mechanism for allocating grid connections is required to determine dates when projects are offered connection to the transmission network. This can involve a centralized process where grid capacity is allocated to existing connection points, such as an offshore hub. This approach can be based on predefined, established projects as part of a project leasing or permitting process.

Export systems might require a separate ESIA and permitting process. Some countries have different permitting frameworks for onshore and offshore infrastructure; this requirement should be determined early on and communicated to the industry. Ideally, grid connection locations should be considered as part of MSP and site selection stages, informed by available environmental and social baseline data. This can reduce the risk of delays at the project permitting and development stages.

Grid connection dates are often on the critical path for project completion. It is important for a developer to be given a firm grid connection date early in the project development lifecycle, so that they can plan the rest of the project efficiently. Project development slowed by waiting for a grid connection adds to LCOE, as it increases the time between early capital expenditure (CAPEX) and revenue, which can discourage investment.

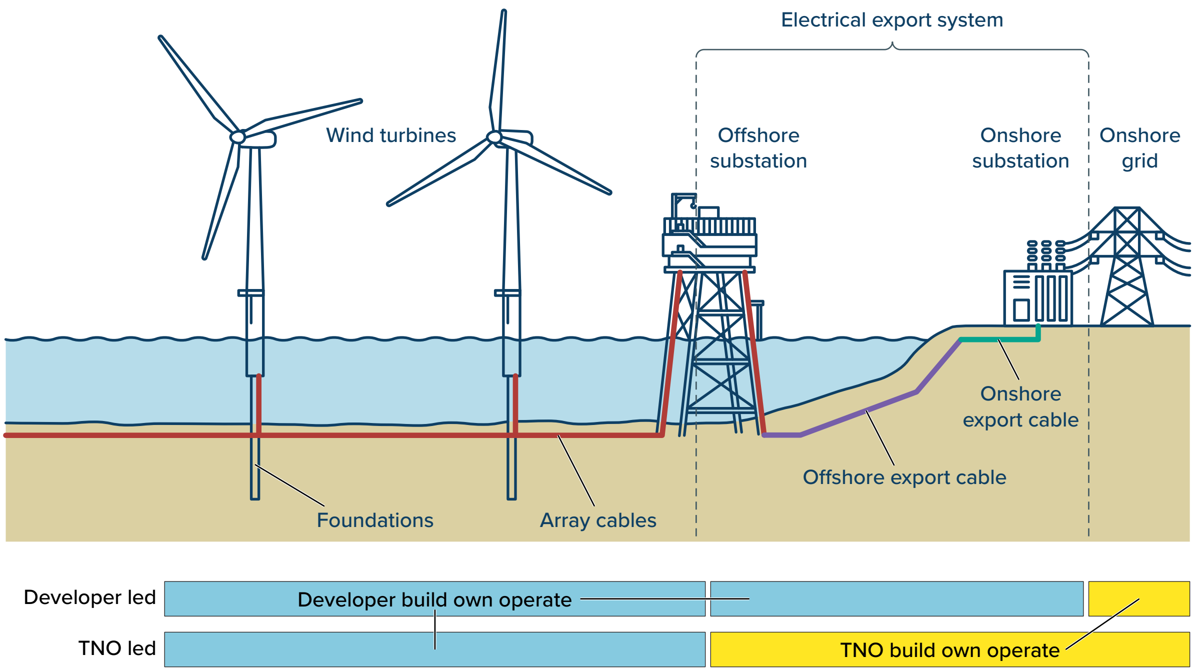
A project developer suffers a significant financial impact if an offshore wind project is installed and then must wait for a grid connection before exporting power. There have been projects where the capital cost has been paid but revenue is delayed for many months until connection is complete. This is most commonly due to delays in completing the export system or delays in upgrading the transmission network. Legally binding compensation mechanisms, such as those paid by TenneT in the Netherlands [63], can help mitigate this risk.

Grid connection costs should be reflective of network upgrade requirements, and use of system charges[57] need to be based on a clear framework [157]. The allocation of costs for connecting a new offshore wind farm to the grid can generally follow one of two philosophies, "deep" or "shallow" charging:

- In a deep charging regime, the connecting party covers the costs for local upgrading of the national transmission system. These costs can be a significant proportion of the total offshore wind project CAPEX.
- A shallow charging philosophy requires the connecting party to only cover costs for the assets to connect to the grid, such as an extension to an onshore substation at the grid connection point. In this case, national transmission system reinforcement costs are recovered over time by socialized "use of system" charges or tariffs.

A deep charging strategy may be simpler to initially implement; however, it can become inefficient and complicated when multiple parties want to connect to the same part of the transmission system. This is because it can be unequitable for a single developer to pay for wider grid reinforcement that other users subsequently benefit from. It can result in additional costs for the first developers to connect to the network.

FIGURE 3.10: Overview of offshore wind farm export system and build/operate approaches



Source: Adapted from [158].

57 Use of system charges are often referred to as a wheeling charge.

Connection Agreement and Grid Code

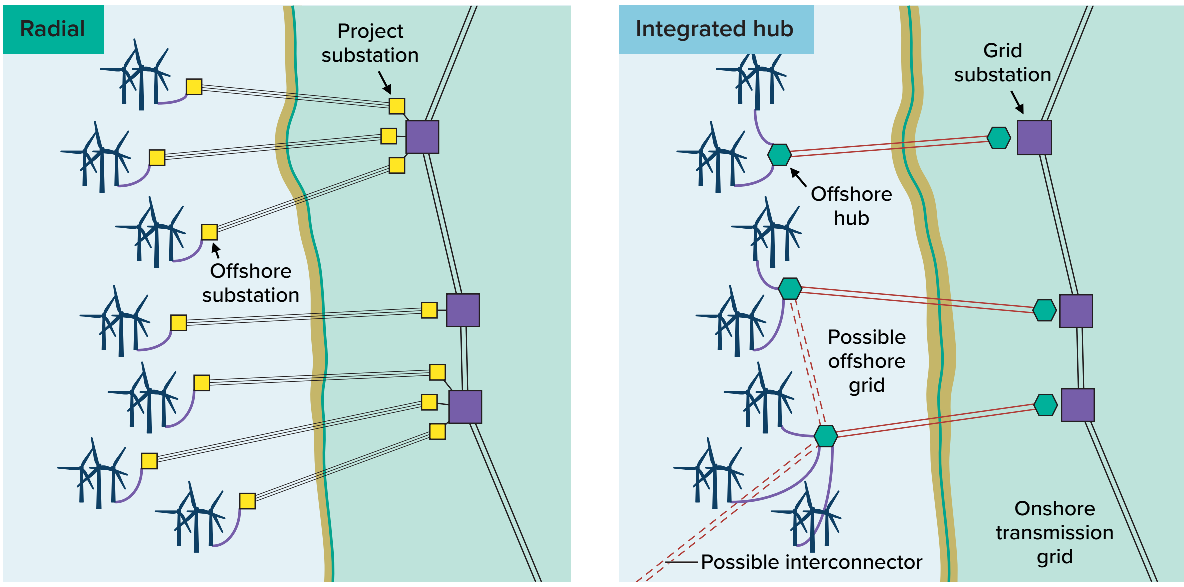
Modifications to grid codes may be required for offshore wind. At the point of grid connection, compliance to relevant grid codes is required. This point is typically defined as being at the onshore substation rather than the offshore substation. Any substation equipment required to achieve grid code compliance can then be installed onshore at a lower cost than offshore. Grid code modifications and how they are implemented (for new and existing plants) need to be carefully considered as there can be material cost considerations. Updates were made in the UK [159] and in Germany [160] to reflect offshore wind requirements. It is recommended where possible that harmonization with international standards is achieved, avoiding additional costs and risks involved with designing for nonstandard grid codes (see section 3.8). The EU developed harmonized grid connection standards in 2016 to support all forms of generators [161].

Well-defined rules for network access, along with mechanisms for curtailment compensation, help reduce developer risk. A connection agreement needs to define whether a connection is eligible for compensation during grid outages and the level of compensation (see Case Study 3.20). Investors are sensitive to how grid access and curtailment risk are managed within the connection agreement and how the project is financially protected against it.

CASE STUDY 3.20: Grid Curtailment Compensation Mechanism in Germany

In Germany, from the start of each year, the first 10 consecutive days or 18 cumulative days of transmission network outages are not compensated, after which compensation is received for 90 percent of the lost production [162]. The periods that are not compensated can affect the revenue of an offshore wind farm; however, since there are clear rules in place, the impact can be modelled.

FIGURE 3.11: Radial and integrated "hub" network designs



Typically limited to ~700–800 MW per offshore substation for HVAC (more if HVDC)

Common in the UK, Denmark, Taiwan

Project specific and often developer-led

Typically 1–2 GW per hub using HVDC

Planned for Germany and the Netherlands

Strategic development and needs to be TNO led as part of a larger plan

Note: HVAC = high-voltage direct current; HVDC= high voltage direct current; TNO =Transmission Network Operator.

Approaches to Export System Design and Ownership

An integrated offshore hub model reduces the number of connection assets required. Offshore wind grid connections can be via a radial system, where each wind farm connects to its own substation and back to the onshore connection point, or via an integrated "hub" system that uses shared offshore substations and export cables (see figure 3.11). Different export system options were compared by the New Jersey Board of Public Utilities when considering which approach to favor [163]. Benefits can be achieved through coordinated grid design, as were recently implemented in the UK (see Case Study 3.21). Each country will have different arrangements and evolving needs, so such reviews are important in enabling best-value solutions.

CASE STUDY 3.21: UK National Grid Offshore Connection Review

In recent years, communities of East England have objected [164] to the onshore grid infrastructure works associated with the offshore wind projects that have been approved off the English east coast. These works have largely been uncoordinated, and cumulatively, have resulted in extensive disruption. As a solution, campaigners asked for better coordination of development and for integrated solutions to be considered to reduce onshore impacts [165].

In 2020, consultation was held with stakeholders to review the future offshore electricity infrastructure needs in the UK. A cost benefit analysis was carried out which showed that a more holistic, integrated approach for export systems of the future wind pipeline could potentially save up to US$8 billion in capital by 2050.

The integrated approach provides material cost benefits, however, is forecast to take longer to implement than a less integrated approach, potentially delaying future projects. Therefore, careful planning is required, which is currently ongoing in the UK [166].

Export systems ownership and operation can lie either with the government, transmission network owner, or private investors. The approach will be influenced by existing government policy on infrastructure ownership**.** This will vary between countries and will depend on the approach taken to the export system design and the existing transmission system ownership model. The consideration of industry capability and regulatory and market structures is required to determine the best approach for a country. See Case Study 3.22, which outlines the approach taken in the UK. Two common models of offshore transmission ownership are explored in table 3.5, each with different benefits and risks. Where a cluster of wind farms are envisaged, there are benefits of ownership being held by the onshore transmission system owner with shared, integrated connection hubs.

CASE STUDY 3.22: Offshore Export System Ownership

The UK

For many early offshore wind projects in the UK, the developer was responsible for consenting, licensing, constructing, and operating all the export system assets, from the turbines to the onshore substation. However, the government considered that this system was incapable of delivering cost-effective and timely connections for this scale of development in a manner that would ensure the integrity of the transmission system as a whole [167].

In 2009, a new offshore transmission license regime was implemented, whereby the energy regulator Ofgem granted export system licenses based on a competitive tender process. In this new regime the wind farm developer has the option to also develop and build the offshore export system; however, the completed transmission assets are subsequently transferred to an appointed offshore transmission owner (OFTO) [168].

The owners receive a regulated revenue stream which is guaranteed for a fixed period (20 years initially and now 18.5 years). Developers recovering the capital invested through the tender process can reinvest in future projects, promoting economic growth. Ofgem reports that this hybrid regime has been effective at providing value for money for consumers and driving competition [169].

The Netherlands

In the Netherlands, the national transmission network operator, TenneT, is also responsible for the offshore wind export systems. This has advantages relating to economies of scale following standardization in substation design, purchasing, maintenance, and knowledge development. Operations by a central body also simplifies compensation payments, flow management, and balancing of supply and demand [63].

To create the cost savings, a standardized alternating current (AC) substation with a capacity of 700 MW has been designed to connect wind farms to the transmission network, using two 220 kV export cables. To further reduce cable costs, future 380 kV subsea cables will be used, when available. For future direct current (DC) substations, the connected transmission capacity is approximately 2 GW, and an onshore converter station via two 525 kV cables will be part of the export system.

The array cables, which connect the wind turbines to the substation, remain the responsibility of the project developer. The wind turbines will be normally connected to the TenneT substation platform through 66 kV cables.

In selecting a model for building, ownership, and operation of export systems, it is important to consider which party can best manage each role. Governments should only proceed with a state-build model when they are confident their delegated authorities can deliver offshore transmission assets in a timely manner for the new industry. In any case, a robust compensation mechanism to cover delays is required. This is due to the high cost associated with any delays to transmission network upgrades or grid connection. A developer-led build, drawing on international specialist expertise, can support quicker and more efficient deployment by parties with a proven ability to manage construction, costs, programs, and risks in this environment (see Case Study 3.23).

CASE STUDY 3.23: Rentel Offshore Export System Approach

In Belgium, for recent offshore wind farms the transmission system operator (Elia) has been responsible for providing the export system through a centralized offshore hub.[a] A number of projects (Rentel, Seastar, Mermaid, and Northwester 2) are being developed in parallel and will connect to this hub.

As the Rentel offshore wind farm was developed earlier than other projects, it was agreed that the developer would build the export system for its wind farm, considering the future projects. This export system was then sold to Elia to form part of the offshore hub. This approach allowed a timely connection for the Rentel project to avoid delays in being able to export its power [170].

a. An offshore hub is a large offshore substation with sufficient capacity to allow several projects to connect, rather than each individual project having its own export system.

TABLE 3.5: Advantages and disadvantages for different export system build and operate approaches

	Transmission network operator build and operate	Developer build and operate
Planning and design	**Pros:** Holistic approach with opportunities to standardize design for economies of scale. Shared assets (single connection for multiple wind farms) can limit environmental footprint. **Cons:** Any standardized design will not reflect specific developer needs (e.g., with respect to innovations).	**Pros:** A single party is responsible for wind farm and offshore grid scope in planning and design stage. **Cons:** Developers typically use different design concepts, which prevents standardization and asset sharing.
Commercial and finance	**Pros:** Transmission network operator benefits from more favorable financing conditions, and a stable pipeline of projects can reduce costs. **Cons:** Larger amounts of (pre-) investment capital is required. Transmission network operators do not face the same market (cost) pressures as developers in competitive tenders/auctions.	**Pros:** Commercial parties could have more flexible financing options such as higher debt shares, which could result in lower weighted average cost of capital (WACC). Competition could lead to cost reductions. **Cons:** A lower potential to reduce societal costs through a coordinated approach.
Construction and interface risk	**Pros:** Offshore wind deployment and onshore transmission network capacity reinforcements are coordinated. **Cons:** Complex interfaces between developer and transmission network operator with different drivers. Could result in stranded asset costs if not properly coordinated.	**Pros:** Single party coordination limits the interfaces and reduces the risk of construction delays. **Cons:** Lack of wider transmission network perspective such as onshore reinforcement not being included in developer scope.
Operations and maintenance	**Pros:** Larger standardized asset base (OPEX reduction potential), higher redundancy, and greater control by transmission network operator. **Cons:** Potential disconnect between the transmission network operator and the developer. This can result in lower availability of the export system.	**Pros:** Where developer also operates the export system, the risk of export cable and platform failure is with party most affected. This allows the operation and maintenance (O&M) of the wind farm and export system to be aligned. **Cons:** Transmission assets typically have a longer design lifetime than a wind farm, which leaves full asset utilization in the long term uncertain, unless developer has long wind farm lease.
Example	Denmark, Germany, the Netherlands	Taiwan, the US

Source: Adapted from [158].

The high complexity, risk, and liability associated with the delivery of the export system is likely to be unattractive to transmission network operators in emerging markets. As table 3.5 outlines, it is critical that the party that designs and constructs the export system does so to the right quality and delivers it on time; otherwise substantial damages could be owed to the wind farm owner. As most transmission network operators do not have experience with delivering subsea interconnectors or offshore construction projects, they are unlikely to undertake this task alone.

Low-cost public finance could be used to finance a project's export system, which would reduce the tariff required by the wind farm. By transferring the ownership of the export system to a grid operator with access to lower-cost finance, the overall weighted average cost of capital (WACC) could be reduced. This could be particularly effective if the financing was on concessional terms and could be provided by development finance institutions (DFIs) such as the World Bank Group, and climate funds such as the Green Climate Fund (GFC) and the Climate Investment Funds (CIFs). The UK and Belgium approaches in Case Study 3.22 and Case Study 3.23 provide relevant examples that could inform this approach in emerging markets. In both cases, the developer is responsible for the design and construction of the export system, and once it is completed, its ownership is transferred to a grid operator.

KEY SUCCESS FACTORS

Related to the export system and grid connection for offshore wind, governments should:

a. Provide clarity for developers through a clear, bankable framework to secure timely grid connections.
b. State the parties responsible for the delivery and operation of the export system, and clearly define the technical and commercial interfaces between assets.
c. Include mechanisms to compensate curtailment of generation output to give developers sufficient clarity of revenue.
d. Keep grid codes applicable to offshore wind, with the aim of harmonization with international standards to avoid additional costs.

Suggested reading materials are found in appendix A and full references found in appendix B.

3.8 Health and Safety

The offshore wind industry in each country needs effective health and safety practices and a culture that protects people and the environment. Workforce safety must be the industry's highest priority.

Global Best Practice

The WBG provides a series of general and sector specific Environmental, Health, and Safety (EHS) Guidelines [171]. When country regulations differ from the levels and measures in the EHS Guidelines to receive financing from the WBG and other international lenders, projects will be required to achieve whichever is more stringent. These guidelines can help inform governments on fundamental good practices for EHS.

Best practice from global training bodies, such as the Global Wind Organization (GWO), G+ Offshore Wind Health and Safety Association, or similar industries, should be encouraged as much as possible. These organizations have an extensive portfolio of technical experience and data that emerging markets can draw on. Globally recognized safety and technical standards [172], along with best practice guidelines [173], have been developed for offshore wind. Many leading offshore wind companies are members of the GWO, which issues training standards and accredits training providers [174]. An example of one of its accredited providers is the Taiwan International Windpower Training Corporation [175], established to support the growth of the industry in Taiwan.

Positive behavior and accountability of every individual across the industry is required to ensure safe practice. This is only possible through having the right culture. Attracting experienced offshore wind project developers into a market can help in this regard. Projects that are successful, in terms of timely delivery and financial return, will have followed strong health and safety guidance.

It is key for health and safety frameworks to be relevant to the local context. Each market will have a unique environment to consider, with existing regulations, local risks, and local cultures. It is also important not to rely solely on frameworks developed for onshore wind, as offshore requirements differ due to the harsher environment.

Partnering and learning from international experiences is recommended. In Taiwan, for example, the safety regulator has benefitted from partnering with the G+ to create guidelines promoting the safe start of its offshore wind industry (see Case Study 3.24). A similar partnership has developed between local governance in New Jersey and the GWO [176].

CASE STUDY 3.24: Taiwan—Health and Safety Development

Taiwan's safety regulator, the Occupational Safety and Health Administration (OSHA) partnered with the G+ and the UK's Health and Safety Executive to draw on international best practice [177]. A memorandum of understanding was signed with the UK's Health and Safety Executive (HSE), and a G+ focal group was set up in Taiwan. This has encouraged leading developers, such as Ørsted to implement the highest Quality, Health, Safety and Environment (QHSE) standards on site for construction of their wind farms, Changhua 1 & 2a [178].

Legislation

Introducing legislation to target improving health and safety culture encourages safety-focused behaviors. Improved culture is the primary method of reducing incidents in an industry. Safety-focused behaviors and leadership from the top down ensure that health and safety is fully embedded in the culture of an industry [157] (see Case Study 3.25).

CASE STUDY 3.25: UK's Health and Safety at Work Act

The impact of the UK's Health and Safety at Work Act is a key example of meaningful change occurring following empowered regulation, with fatal injuries to employees falling by 87 percent between the enacting of the legislation in 1974 and 2014 [179]. While not specific to offshore wind, this demonstrates the impact a successful health and safety regulator can have on industry culture and accident statistics.

The existing, national health and safety regulatory framework should be assessed for gaps when considering offshore wind. A national health and safety authority would likely be the relevant overseeing authority for offshore wind. The roles and jurisdictions of each regulatory body or stakeholder involved must be carefully defined to provide clarity for developers. This was successfully achieved in New York with a targeted technical study [180].

KEY SUCCESS FACTORS

Related to health and safety for offshore wind, governments should:

a. Combine international best practice with local considerations.
b. Involve all stakeholders to ensure legislation is fit for purpose and responsibilities are clear.
c. Drive health and safety-focused behaviors through leadership and culture that are fully embedded in the industry.

Suggested reading materials are found in appendix A and full references found in appendix B.

3.9 Standards and Certification

Wind farm component design, manufacture, installation, and operation following technical standards help to reduce project risk.

International Standards for Wind Farm and Key Component Design

Well proven wind industry standards are used by established suppliers. Standards such as the IEC61400 suite [181] are specific to the wind industry and capture good practice developed over many years. Established suppliers routinely deliver to these standards, and new suppliers should be encouraged to do likewise to maximize market opportunity. Standards include a reference to representative site conditions. These continue to be developed to cover natural considerations in emerging markets, for example different seismic and extreme wind and wave conditions. Governments should support the ongoing development of these standards through engagement with the international standards organizations.

Many components are designed to be used in multiple offshore wind markets. As well as meeting wind industry standards, wind farm components are designed to meet DIN[58] [182], EN[59] [183], the International Organization for Standardization (ISO), [184] and other internationally recognized standards for design and manufacturing. Accepting these standards, rather than introducing onerous national standards, can avoid additional costs and extended delivery times for parts. Governments should seek to harmonize between relevant international and national standards where relevant; for example, this was carried out in 2014 by the British Standards Institute (BSI) for offshore renewables [185].

It is important to note that offshore wind standards are not directly equivalent to those for onshore wind. Engagement with industry can help to facilitate the correct interpretation of the available standards, avoiding unnecessary delay.

The Role of Certification Authorities and Technical Advisers

Wind turbines and other standardized components are type certified to international standards. This process is carried out by international certification authorities, such as Bureau Veritas, DNV, Lloyd's Register, and TÜV Nord, that are active across the wind industry and trusted by investors. Developers and technical advisers provide an additional level of confidence through due diligence assessments based on their experience.

Project finance often requires third-party project certification against IEC standards. This increases assurance that the offshore wind project has been designed and implemented considering the conditions relevant to a specific offshore wind farm project, and following good practice captured in the standards.

Governments should allow industry and investors to determine what type certification and project certification is required to manage risk for a given project. Industry risk management processes, including those used by underwriters, have helped find a reasonable balance between independent verification and supplier accountability, enabling ongoing innovation while managing risk. Germany is an example of a country that imposes more local requirements, especially around onshore and offshore wind turbine structural integrity [186].

58 DIN: Deutsches Institut für Normung – or German Institute for Standardisation.

59 EN: Europäische Norm – or European Norm. Usually referred to as European Standards.

KEY SUCCESS FACTORS

Related to standards and certification for offshore wind, governments should:

a. Support the ongoing development of standards to ensure local applicability, through engagement with the international standards organizations.

b. Avoid imposing new national standards that introduce additional costs and extended delivery times for components.

c. Allow industry and investors to determine what type certification and project certification is required to manage risk.

Suggested reading materials are found in appendix A and full references found in appendix B.


KEEP
OFF

4 DELIVERY

4.1 Introduction

The frameworks discussed in chapter 3 provide the regulations and processes to give offshore wind developers a clear project development pathway. They cover the steps from project concept to construction. Beyond setting policy and enabling frameworks, to sustain a long-term industry, policy makers should consider “how else can we support the successful delivery of this new industry?”

Important questions raised by creating policy and frameworks, include:

- How can a local supply chain be developed that maximizes economic benefits and helps meet policy goals?
- Who is responsible for preparing the port infrastructure to support the delivery and operation of projects?
- Should the capacity of transmission networks be coordinated to facilitate the connection of projects?
- Where will the financing for these projects and infrastructure come from?
- What are the differences in the financing needs for offshore wind in comparison to other projects?

This chapter discusses topics that are essential to support the ongoing delivery of offshore wind. Governments have an important role in partnering with industry to help answer some of these questions and to proactively support the delivery of this new industry.

Government oversight in partnership with industry groups has proved successful in established markets. This can be through establishing a government-industry council, for example the Offshore Wind Industry Council (OWIC) [42] and the Scottish Offshore Wind Energy Council (SOWEC) [187] in the UK, and the Public-Private Council on Enhancement of Industrial Competitiveness for Offshore Wind Power Generation in Japan [64]. The purpose of these groups is to ensure clear communication between key industry stakeholders and government bodies that are responsible for policy and frameworks so that all understand the challenges and can contribute to solutions. Such communication was critical to the second industry “deal” in the UK (see Case Study 2.1).

Beyond the topics covered in sections 4.2 to 4.5, other important areas for governments to consider in managing the delivery of offshore wind are:

- Learning and adapting from experience as well as adopting evolving best practice from other markets.
- Responding to technological, economical, and political developments.
- Managing industry-wide risks.
- Encouraging collaboration and innovation to solve local issues at a national level.

4.2 Supply Chain

Offshore wind offers local economic benefits and needs a level of local supply chain development for it to be successfully delivered.[60] This section links closely with supply chain policy discussed in section 2.4.

Large-Scale Investment

Public funding to support private investment can enable decisions where there would have been insufficient visibility. Offshore wind needs investment in new manufacturing facilities to continue to provide the increasing volume of supply required to reduce levelized cost of energy (LCOE), but individual suppliers can often find it hard to justify, especially in markets that are new to them. Different countries have different fiscal and financial mechanisms to support such investment, especially where investment is made to deliver a single project but will need to be amortized over a long period. Mechanisms include:

- Targeted competitions, whether for capital support [188] or research and development (R&D) support [189].
- Tax incentives specifically for offshore wind [190] or for industry more generally.
- Use of export credit agencies (ECA) to support local suppliers acting overseas (see section 4.5).

Local Industrial Clusters

Facilitating the development of industrial clusters through supportive policies, funding for business networks, and other initiatives encourage industry collaboration and investment. Ports provide a hub around which clusters of related offshore wind businesses can develop, also improving logistics. Both through targeted development policies and the unplanned growth of interrelated industries, many ports have become locations for industrial clusters. Several notable port-centered industrial clusters have developed over the last 50 years, for instance, those in Antwerp (Belgium) Colón (Panama), Dubai (United Arab Emirates), Hamburg (Germany), Houston (US), Marseilles (France), Norfolk (US), Rotterdam (Netherlands), and Yokohama (Japan) [191]. Specifically, in relation to offshore wind, this has been observed at the Port of Esbjerg (see Case Study 4.1).

CASE STUDY 4.1: Support for Industrial Clusters

Denmark—Esbjerg Port

The Danish Energy Innovation Cluster was set up to support industrial cluster development and worked with Esbjerg Municipality and industry association Wind Denmark to support a network of businesses which can benefit from synergies and shared clients [192]. The companies at the Port of Esbjerg represent a large part of the supply chain for the wind industry. The port has already been involved with over 50 offshore wind farms [193].

UK—Humber and Teesworks

In 2020 and 2021 the Department for Business, Energy and Industrial Strategy (BEIS) introduced a number of initiatives to encourage port development to support offshore wind and industrial clusters. The Offshore Wind Manufacturing Investment Support (OWMIS) scheme [194] has supported the creation of industrial clusters through investments at Humber (US$104 million) and Teesworks (US$28 million). Following this investment, General Electric (GE) announced they were to open a new offshore wind blade manufacturing plant in the UK at Teesworks [195], evidencing that this approach helps attract international companies to support the offshore wind market.

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60 Section 2.4 provides information on the opportunities for supply chain development and bigger-picture activities to support supply chain development. This section discusses some of the interventions that have been used to aid supply chain development that could be adapted for use in emerging markets.

Supplier Education and Support

Supply chain gap analyses are useful in a country in the early years of offshore wind to establish if there are gaps in the supply chain and which of these can viably be filled by an in-country supply. Such studies should not solely look at the balance between supply and demand locally, but also consider cost-effective overseas supply. Studies are useful in providing information to governments, industry purchasers, and suppliers. They are usually commissioned by governments, trade associations, or other stakeholders [196] [197] [198] [199].

Incubation programs help to coach suppliers and provide education regarding export opportunities. Offshore wind offers a diversification and growth opportunity for suppliers from parallel sectors. The sectors with greatest opportunities for synergies are oil and gas and marine engineering. Programs should be tailored to specific needs of the industry, providing events and individual company support to help companies win first contracts, grow, and (if relevant) export. In the UK, the current flagship program is mainly industry funded, as a result of the last government-industry “deal” [41]. Other programs can be national or regional, broadly or narrowly focused on offshore wind, and free or as part of the services of a membership organization. Occasionally, individual industry players fund programs [200] as a way of meeting their supply chain needs.

Good communication of supply opportunities benefits new suppliers. National and regional wind industry trade bodies can take on this role with digital market intelligence [201] [202]. National and regional membership organizations with wider energy interests often have a high focus on sharing opportunities in offshore wind [203] [204]. Energy share fairs, as pioneered in the oil and gas sector, can also play a role [205]. In any case, governments should promote the sharing of market information in the early stages of industry development.

Industry Support Activities

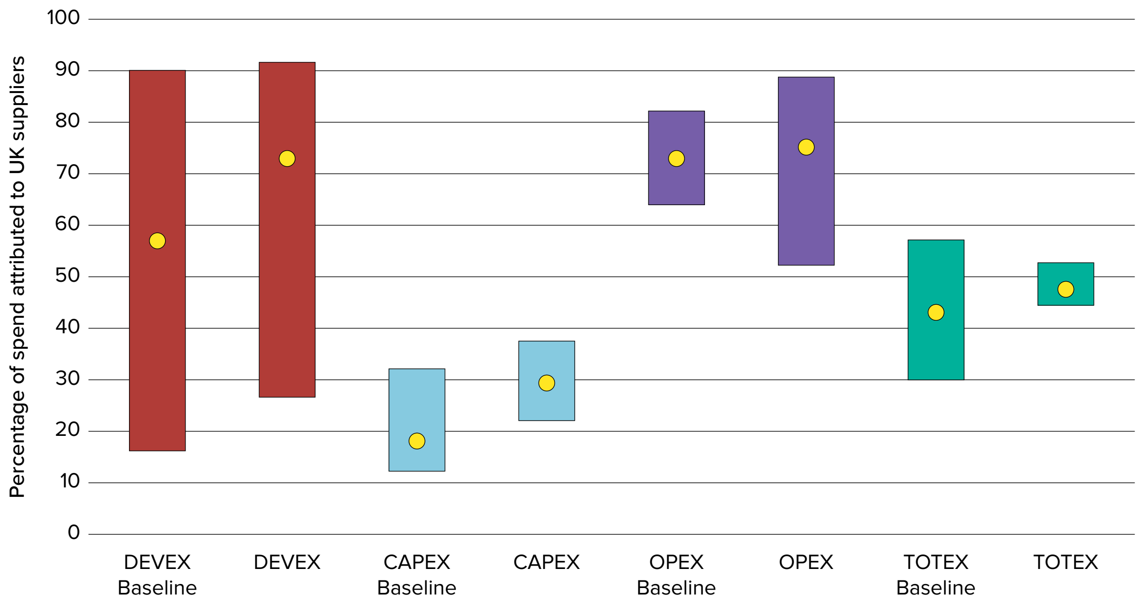
Supply chain databases play a useful role if well delivered. It is helpful for organizations seeking to grow the supply chain and for purchasers in emerging markets to understand the capability of current and potential future suppliers. Many national and regional wind and wider energy trade bodies have databases, and some government organizations also operate them [206]. A well delivered database is up to date, has verified, accurate information and does not simply rely on information provided by suppliers.

Prequalification databases help make supplier registration processes more efficient. One step for suppliers is to prequalify for a supply to key offshore wind players by submitting a wide range of corporate information demonstrating that they are a viable option. Based on this, purchasers draw up a short list of bidders for supply packages. Purchasers in offshore wind typically operate their own prequalification databases, but in other sectors (for example oil and gas and utilities) there is more coordination, and independent companies provide such services to a range of players, thereby reducing the workload for suppliers as they do not need to provide information in different formats for many purchasers [207]. Governments should consider whether any intervention in this area is needed.

Measuring and reporting local content helps enable meaningful dialogue about local economic benefits. In dialogue, it is helpful to have a language and robust definitions so that all parties are clear about the basis of government targets and reports by industry. The Taiwan government issued a clear list of components it required to be supplied locally. The UK industry and government collaborated to develop a standardized methodology for measuring and reporting percentage project lifetime local content and set aspirations, rather than fixed requirements [208]. See also Case Study 4.2. Japan [64] and Poland [209] have announced an intent to follow similar processes to UK.

Figure 4.1 shows output of industry analysis of increased local content after measurement was introduced.

FIGURE 4.1: Industry report on increased UK content of UK offshore wind farms, against earlier baseline [210]



Source data: RenewableUK [210].

CASE STUDY 4.2: UK Content Methodology and Supply Chain Plans

To enable clear communication about local supply, the UK government and industry worked together to establish the UK Content Methodology [208] that has been used for six years now to document UK content on offshore wind projects. Systematic aggregate reports on local content using the methodology have also been published [210] [211].

To drive focus on innovation, skills, and competitive local supply, the UK government mandated that before any developers could bid into its revenue support mechanism for offshore wind, they needed to have their supply chain plan approved by government. Guidance for drafting plans and redacted plans of winning bidders have been published [212] [213]. With an increased focus now on local economic benefit, at the time of writing the government was consulting on strengthening this process so it can hold developers to the commitments they make in their supply chain plans, but it is unlikely to impose formal local content requirements.

In 2021, during the ScotWind seabed leasing round in Scotland, developers were required to submit a Supply Chain Development Statement (SCDS). The ScotWind leasing process did not impose any requirement on the level or location of expenditure and did not form part of the application scoring; however, it did require developers to set out their commitments and ambitions relating to local supply chains. Once selected, the commitments of the preferred developers will form the basis of the lease option agreement [111].

It is important that contract law is fit for offshore wind. This enables a robust but fair allocation of risk and reward, with provision for dispute resolution. The offshore wind industry has successfully used a range of standard bases for contracting, including from the International Federation of Consulting Engineers (FIDIC) [214], Leading Oil and Gas Industry Competitiveness (LOGIC) [215], and new engineering contract (NEC) [216]. If needed, governments should help drive good practice, including via industry collaboration, to avoid experiencing repeat issues.

An important ongoing focus for government should be enabling further LCOE reduction. The impact of any initiatives on LCOE should be considered, as offshore wind will deliver the greatest long-term benefits if it continues to reduce LCOE.

Knowledge and Skills Development

Skills development programs have been used successfully in different markets. Local skills studies and career opportunity assessments can play important roles in defining skills needs (the types of jobs that are needed) and raising awareness of opportunities, for example, in Humber, UK [217], New York [218], Virginia [219], and the US more generally [220]. Once needs are defined, governments and industry regularly work together to help develop skills [221] [222]. Sometimes this has been linked to retraining as part of the energy transition from fossil fuels to renewable energy [223].

There needs to be a continued focus on equality and diversity. Key to unlocking accelerated improvements will be a collaborative effort between schools, universities, industry organizations, companies, and policy makers [224]. Specific measures can span from engaging and attracting talent by leveraging existing diversity-focused networks to introducing initiatives, such as reverse mentoring for leadership, to gain a different perspective and address culture development in the industry.

Raising knowledge across the industry helps improve decision-making. Governments should consider whether they need to encourage relevant stakeholders to establish opportunities for industry learning. For example, in the UK, The Crown Estate arranged days for construction project directors to meet and share experiences. It also initiated System Performance, Availability and Reliability Trend Analysis (SPARTA) [225], an initiative to share operational reliability data between project developers. In Germany, the government supported a major research project on offshore wind meteorology, with learning relevant across the industry [226].

Enabling learning from suppliers in established markets is an efficient way to improve local supply. This is best achieved through encouraging joint ventures and joint industry innovation projects involving local companies. International companies will want to see sufficient local opportunities to warrant engagement with local suppliers. Suppliers new to offshore wind can be surprised at the efficiency, quality, and low cost of supply to offshore wind, and this takes time to master.

Workers from related industries often have skills that can be quickly adapted to suit offshore wind. Recent analysis by Global Wind Energy Council (GWEC) shows that 3.3 million new wind power jobs can be created globally over the next five years thanks to major industry expansion [227]. Offshore oil and gas, and marine construction are most closely related to offshore wind and are the most common sources for skills transfer. Ex-military personnel are often excellent candidates for operation and maintenance (O&M) roles, and some offshore wind developers actively seek to employ veterans [228]. Policy makers should also consider the impact of offshore wind development on the jobs in other sectors; the redundant workers from the closure of a coal mine or power station, for example, could be retrained to work in offshore wind, thereby adhering to the principles of a “just transition” to a climate-neutral economy [229] [230].

Encouraging sharing of project data and generation statistics in the public domain. Good examples of this are the Danish wind turbine register [231], which is maintained by the Danish Energy Agency and The Crown Estate’s annual offshore wind report [232]. This helps drive competition across the supply chain and supports best practice between projects.

Removing Barriers to Competition

Governments should carefully consider current cabotage laws and consider temporary exemptions for offshore wind in the early days of the industry. The use of foreign vessels for installation and service of offshore wind farms is required due to the specialized nature of the activities. Cabotage laws, such as the Jones Act in the US [233], Schiffssicherheitsverordnung in Germany [234], and “closed ports” in Japan [235], can restrict the use of foreign vessels and increase the costs of project construction and operations. It is important for governments to address any other such areas where competition is reduced through legislation or local practice.

Innovation, Research, and Development

Publicly funded innovation programs can reduce LCOE and help increase the amount of local supply. An important entry point for companies into offshore wind is providing innovative solutions with applications in offshore wind and beyond. Each offshore wind market will have characteristics that demand innovation and local solutions, and governments have a role in establishing innovation needs [236] [61]. Support can be provided through a combination of grants, loans, or incubation programs, which are either general or specific to offshore wind [189], with a range of funding options available (public, partly, or fully industry funded) [237]. Some countries have established publicly funded research and technology organizations (RTOs) with a high focus on wind [238] [239] [240] [241]. RTOs help local and international collaboration and focus on key areas of innovation, as well as publicizing support opportunities [242].

Workshop test facilities and onshore and offshore test sites also play important roles in the route to market for innovations and suppliers that are new to offshore wind. Workshop test facilities play an important role in the development of new turbines, foundations, and other components. Such facilities enable key conditions to be simulated, which enables the testing of new technologies to determine whether they can withstand offshore environments. Example facilities include those for drivetrains at Clemson University [243], blade bearings at Fraunhofer IWES [244], blades at ORE Catapult [245], and complete turbines at the Østerild Test Center of the Technical University of Denmark [246]. Offshore test sites enable innovations to be demonstrated at part- or full-scale in small volumes. Any decision about public investment should consider how new facilities will fit in a global network of facilities. For example, there will typically be no need to test or demonstrate the latest wind turbine technology in multiple markets. Governments in emerging markets should focus on supporting any local innovators or innovations needed to reduce LCOE for their specific market.

An important new opportunity for the supply chain is in the journey to net-zero and the circular economy. Offshore wind itself has significant environmental benefits, but project developers are seeking ways to further reduce the environmental footprint of their supply chains. Case Study 4.3 presents examples of large-scale activities. Across the supply chain, there are becoming more opportunities for using recycled materials and refurbishing components rather than replacing them.

Floating offshore wind will also create new supply opportunities as the deployment of this technology accelerates through this decade. Different floating foundations, installation methods, and cable support arrangements will enable new suppliers to enter the market and help drive innovation.

CASE STUDY 4.3: Reducing the Carbon Intensity of Offshore Wind

A key contribution to carbon intensity of offshore wind comes from manufacturing iron and steel components, especially towers, and foundations and large cast items. HYBRIT, a partnership between steelmaker SSAB, energy utility Vattenfall, and mining company LKAB has started test operations at a pilot “fossil-free” steel-making plant using hydrogen instead of traditional coking coal. [247]

Another key contribution is from materials that have low re-use value, such as composite turbine blades that today are burnt, buried, or reduced to granules to be used as a filler material. Projects such as Decomblades [248], SusWind [249], and ZEBRA (Zero Waste Blade Research) [250] are enabling collaboration to increase the residual value of existing blade materials, design blades for increased future recyclability, and develop materials for use in blades with higher recycled content.

KEY SUCCESS FACTORS

Related to supply chain development for offshore wind, governments should:

a. Create the market environment and confidence to invest in a local supply chain.
b. Listen to industry to help focus attention on the most important areas.
c. Consider supply chain growth as part of the wider regional and international offshore wind industry, focusing on local strengths, and opportunities for export as well as local supply.
d. Deliver skills and supply growth through collaboration with industry and educational institutions.

Suggested reading materials are found in appendix A and full references found in appendix B.

4.3 Ports

Nearby ports are essential to enable the construction, operation, and maintenance of offshore wind farms.

Port Requirements

Offshore wind projects have different port requirements at different stages in their lifecycle. Large ports are required during construction for component manufacture and assembly prior to installation. Smaller ports are required for operations and maintenance activities. Details are outlined in table 4.1 and a typical port scene during the construction of a project is shown in figure 4.2.

FIGURE 4.2: Components for an offshore wind farm at Eemshaven port

Source: Koos Boertjens / WindEurope [252].

TABLE 4.1: Ports for fixed offshore wind—typical attributes for a 1 GW fixed foundation wind farm based on 2020 data with allowance for next generation turbine technology[61] [251][62]

	Construction		Operations and maintenance (O&M)	
	Manufacturing	**Marshalling/assembly**	**Crew transfer vessels**	**Service operation vessels**
Description	Components such as turbine nacelles, blades, towers, foundations, cables, and offshore substation topsides are too large to be transported by road and must be manufactured in ports.	A large port space is needed for one to two years during construction of an offshore wind project. Components will be preassembled at a port before loading onto ships for installation. This will require a large working space and suitable weight bearing surfaces.	Crew transfer vessels (CTVs), length 18 to 25 m, for daily operations are generally small enough to use local harbors with limited adaptation.	Ships with accommodation service operation vessels (SOVs), length 60 to 90 m, may be used for wind farms further from shore, but these are still smaller than the ships used during the construction stage. SOVs can stay offshore for several weeks.
Water depth at entrance and quayside	9–12 m below LAT[63]	9–12 m below LAT	3–4 m below LAT	7–8 m below LAT
Preferred maximum distance to offshore wind zone	Less sensitive to site location if a marshalling port is used.	200 km	50–75 km (depending on vessel size)	>75 km
Harbor entrance width	50–60 m	50–60 m	15–20 m	20–25 m
Air draft requirements	40–100 m	40–100 m	12–20 m	30–50 m
Area requirements	4–12 ha+ onshore area for fabrication and storage of components, with suitable covered facilities.	4–8 ha as a minimum, 10–20 ha ideally. Dependent on logistics.	0.75–1.50 ha onshore area for facilities. 1–2 ha sheltered water area for vessel berthing.	0.75–1.50 ha onshore area for facilities. 1.5–3 ha sheltered water area for vessel berthing.

Other important attributes for the offshore wind industry include:

- Quay length (500 m will accommodate up to two mid-sized jack-up installation vessels),
- Quayside bearing capacity (20–30 metric tons/m2 are required for load-out to adjacent vessels with storage areas needing a capacity of at least 10 metric tons/m2),
- Water space suitability (turning area and sheltered areas), and
- Space for manufacturing facilities and working space.

No or minimal vessel access restrictions. This is particularly important for operation and maintenance (O&M) purposes and for marshalling/assembly.

61 Next generation technology refers to projects using 15 MW scale turbines that are likely to be installed between 2025 and 2030.

62 The requirements shown are for a nominal 1 GW fixed foundation offshore wind project and are dependent on vessel types and port specifics. The values presented are typical values without any local context. As turbine scale increases these requirements will change. Port requirements for floating wind depend on the foundation concept.

63 Lowest astronomical tide (LAT) is defined as the lowest tide level that can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions.

Floating offshore wind projects may require significantly greater quayside water depths; however, the industry is at an early stage and is evolving rapidly. Demonstrator projects using spar foundations, such as the Hywind projects assembled in Norway [253], have used vertical fabrication and assembly methods partially alongside quays with very deep water (+25 m), followed by final assembly in deep, sheltered areas of fjords (often not available in other markets). Semi-submersible foundation technologies currently under development are likely to need quayside water depths of 14–18 m. Port requirements for floating offshore wind are expected to become more certain in the next five years, as more demonstration and early commercial projects are installed, including in the ScotWind zones [254], the Celtic Sea [100], and in the waters of France [255] and Spain [256].

Early Planning and Use of Existing Ports

Governments have an important role to ensure that the port infrastructure is suitable and established in a timely manner to support its offshore wind strategy. To build a port, or to undertake major upgrades, takes a minimum of two years. This timing is highly dependent on permitting and in some cases can take up to ten years. Governments, private ports, offshore wind developers, and major manufacturers should plan for making any necessary port upgrades in good time (see Case Study 4.4). To prevent costly delays to (or inefficiencies in) project construction, it is important to avoid bottlenecks in port availability and to ensure access to reliable specialized vessels for installation.

CASE STUDY 4.4: New Jersey Wind Port

The New Jersey Wind Port will be a purpose-built 80+ hectare component manufacturing and marshalling port. The port plan has been developed to deliver against an expected pipeline of future projects, with 7.5 GW of offshore wind in New Jersey by 2035 and further projects along the US east coast.

The New Jersey Economic Development Authority (NJEDA) estimates the project will cost US$300 to US$400 million, which will be paid for by the state. As well as encouraging major infrastructure investment and creating more than 1,500 jobs, the development will receive US$100 million in offshore wind tax credit to support the local supply chain. The New Jersey Wind Port is expected to support up to US$500 million of new economic activity within the state and the region each year. [257]

Governments should assess and communicate the suitability of existing port facilities that could be used for construction or operations of offshore wind projects. This will help to determine any upgrade or new ports required. Established and emerging offshore wind markets, such as the UK [251], the US [258], India [259], and Taiwan [260] have published port infrastructure studies. Suitable existing ports provide an advantage by reducing the risk of delays and costs incurred to early projects due to new infrastructure being built. Shipbuilding industries or oil and gas industries often use ports of a scale useful to the offshore wind industry. Ports which are located close to project sites are beneficial as they reduce transit time and hence cost.

Port investments need to be future-proofed by being able to adapt to accommodate new technologies. This includes consideration of larger turbines greater than 20 MW and floating offshore wind turbines, particularly in markets with water over 50 to 60 m in depth, which is most suited for floating wind.

Ownership and Funding

Existing port ownership structures can inform the options available for offshore wind ports. Ports can be fully owned and operated by the government (public service port), private business (private service port), or a hybrid mix of the two (landlord port or tool port). To advance port developments, governments can follow one of two frameworks [191]:

- A private market–based framework.
- A public investment–based framework.

A comparison publicly and privately owned ports is given in table 4.2. Most large ports worldwide are organized according to the landlord model and increasingly operate as autonomous organizations with a commercial focus (private market–based framework). They need to have confidence in a pipeline of projects which will generate sufficient return on investment to finance new investments. However, public investment in the port sector is still common in many countries, including in Rotterdam and Esbjerg (see Case Study 4.5).

Governments have socioeconomic objectives in addition to objectives relating to direct financial returns. These objectives include job creation, and environmental and tax income. However, the allocation of government funds is a complex decision with many factors. The investment payback for small port expansions are 3 to 5 years, for moderate scale developments 10 to 15 years, and for new ports can be greater than 25 years. Certainty of future port demand is important for private infrastructure investors. Investments in manufacturing, marshalling, and assembly ports can require public support to mitigate the potential under-utilization [261], as they are only used for one or two years for each wind farm. Investment risk mitigation can be achieved by the following:

- Early engagement with developers and stakeholders to understand the requirement and project pipeline.
- Commitment or co-investment from government or industry if large investments are required that would not otherwise be delivered via a purely private finance model.
- Designing multifunctional ports that host fabrication facilities as well as marshalling/assembly, helping to diversify revenue streams and improve risk profile.
- Diversification to serve multiple industries rather than relying solely on offshore wind.

TABLE 4.2: Pros and cons of publicly owned vs privately owned ports

Pros	Cons
Publicly owned ports	
Higher focus on economic growth generation. Control and coordination of national strategies and investments.	Political influence in decision-making. Lack of competition. Likely to have higher levels of inefficiencies in management and operations.
Private ports	
Driven by market and profit oriented. Likely to have more efficient management, productivity, and effective extraction within the value chain.	Needs confidence in demand to build business case. Job creation and economic growth of a region not a priority. Financing can be more expensive for private organizations.

CASE STUDY 4.5: Port Ownership

Private Ownership

Ports in private ownership that serve the offshore wind industry include Green Port Hull in the UK, owned by ABP, whose investment case has been supported by Siemens-Gamesa developing an offshore wind blade factory at the site, or Great Yarmouth (owned by Peel Ports) that was the installation base for Sheringham Shoal, Lincs, Scroby Sands, and East Anglia ONE.

Government Ownership

Many offshore wind ports are government owned or partly government owned, such as the Port of Rotterdam, the largest port in Europe, which is jointly owned by the municipality of Rotterdam and the Dutch State Esbjerg Port in Denmark, which is owned by the local municipality.

Looking beyond direct public ownership, ports can receive fiscal exemptions, subsidies, grants, or other forms of government support [262]. These help to value the external benefits that investment in a port brings to the wider economy. As a result, manufacturing facilities can be more competitive, supporting the development of industrial clusters, which increases local content and gross value added[64] (GVA) growth.

Import Duties and Freeports

Freeport status can provide a competitive advantage for a port, enabling it to attract business from offshore wind projects in the region [263]. Ports traditionally form part of the national territory and contribute to government revenues through import duties. Many countries worldwide operate freeports [264], which operate as special economic zones within which customs rules, tax duties, and/or administrative requirements are relaxed for goods remaining within or transiting through the port area. Some freeports, such as those in China, cover a large area and accommodate manufacturing facilities on-site. This can help to attract supply chain industries and establish industrial clusters.

KEY SUCCESS FACTORS

Related to ports for offshore wind, governments should:

a. Ensure existing port facilities are assessed to determine any required upgrades or new ports for long-term offshore wind manufacturing and assembly.
b. Establish effective ownership and funding models to enable necessary investment.
c. Determine whether to grant freeport status to relevant locations.

Suggested reading materials are found in appendix A and full references found in appendix B.

64 Gross value added (GVA) is an economic productivity metric that measures the contribution of a corporate subsidiary, company, or municipality to an economy, producer, sector, or region.

4.4 Transmission Network

A robust approach to transmission network planning and upgrades is required to give industry confidence that projects can be connected to a sufficiently strong transmission network.

Capacity Planning

It is important to consider the anticipated pipeline of future offshore wind to plan for efficient integration into the onshore transmission network. Offshore wind farms typically have large capacity grid connection requirements. A regular, holistic assessment of the transmission network capacity required across the electricity system for offshore wind, other new generating capacity, and changing demand is needed. This maximizes the benefits of strategic network investments and reduces the risk of stranded transmission network assets if individual projects are not progressed. Anticipated future grid connection availability can also help to inform spatial planning and the prioritization of different areas for leasing and procurement.

As variable supply increases on a transmission network, the role of interconnectors, storage, and demand and supply management becomes increasingly important. For interconnectors over long distances, this will usually require the use of high voltage direct current (HVDC) technology [265]. To smooth out the energy supply in periods of low wind speeds, the exchange of electricity with neighboring markets can be beneficial for balancing fluctuating supply and demand, and should be assessed as part of a holistic transmission system design. In addition, demand response and energy storage can provide system flexibility that can help align renewable energy generation with demand [266].

Network Upgrade Coordination

The efficient integration of offshore wind into the transmission network requires coordination across multiple stakeholders. Key stakeholders include:

- Offshore wind farm developers.
- Transmission network operators and owners.
- Energy regulators.
- Government.

For transmission network upgrades, clearly defined roles and responsibilities are needed so offshore wind developers know how they are to engage with the process. The design of upgrades is an iterative process and can introduce uncertainty in the timing and capacity that will be available for offshore wind projects. A large strategic network upgrade therefore requires coordination between the transmission network operators and project developers as part of long-term network planning.

Grid support capabilities[65] and sufficient transmission network capacity can be encouraged by policy incentives. This can be through the use of system charges, which can encourage a connection at points on the network with greater capacity or closer to demand. Policy incentives can also include mechanisms to align generation profiles with demand, and incentivize forecasting generation output of dispatchable generation sources [267].

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65 Grid support capabilities means the ancillary services provided by a generator to help maintain desired frequency and voltage for the transmission network.

KEY SUCCESS FACTORS

Related to the transmission network, governments should:

a. Consider the anticipated long-term pipeline of future offshore wind when planning transmission network upgrades, to ensure timely connection of offshore wind farms.

b. Coordinate with stakeholders to reduce uncertainty related to transmission network upgrade timing and capacity.

Suggested reading materials are found in appendix A and full references found in appendix B.

4.5 Financing

Offshore wind is a highly capital-intensive industry requiring significant participation from the banking sector and the capital markets.

Industry Record

The offshore wind industry has a strong record over the past decade, and financiers have grown increasingly comfortable with the technology. Since 2010, US$68 billion[66] has been deployed to finance offshore wind in the UK and US$37 billion in Germany. Despite the COVID-19 pandemic, 7.1 GW of new capacity was financed in 2020, raising US$32 billion, including for 1.5 GW Hollandse Kust Zuid (1–4) and 2.4 GW Dogger Bank A and B [189]. Both balance sheet financing and limited recourse project financing have been used for offshore wind. Green bonds were issued by Ørsted in 2020 for a project in Taiwan [268] and by Iberdrola in 2021 for projects in Germany and France [269]. Most projects have used limited recourse project financing, demonstrating the degree of maturity and confidence built by the industry and financiers. Typically, international debt is cheaper than local debt and hence will help lead to lower LCOE. Attracting experienced international developers that bring the experience of project financing, and the confidence of international lenders, is important for emerging markets.

Macroeconomic Considerations

Governments need to consider how policy decisions affect access to liquidity while managing the risk exposure to the public sector. Due to the large capital requirements and the complexity of offshore wind financing, projects carry significant development, construction, and operational risks. Financing ever larger projects has challenges, even in established markets. In addition, there are other risk factors to financing, such as rapid technical innovation to deploy larger turbines farther from the shore and in deeper water, or the phasing out of revenue support in certain markets. Policymakers should carefully consider how their decisions affect the ability to raise financing. This includes:

- Allocation of interest rates risk.
- Inflation risk.
- Foreign exchange risk.
- Risks of changes to the corporate tax rate.
- Merchant power price risk.
- Commodity price risk.

66 1.22 exchange rate used from euros to US dollars.

Offshore wind has so far mostly been developed in countries with relatively stable macroeconomic environments and an advanced availability of hedging products and strategies, which has limited availability in many emerging offshore wind markets. This impacts financing as it can limit the number of investors willing to invest. It can also reduce the available percentage of debt finance and the tenor of loans, as well as increasing the cost of borrowing.

The experience of international financiers will be vital for offshore wind in emerging markets. Experienced international banks, development finance institutions[67] (DFIs), international financial institutions[68] (IFIs) (such as the International Finance Corporation), and export credit agencies[69] (ECAs) (such as Denmark's Eksport Kredit Fonden and Germany's Euler-Hermes) can help to raise large amounts of long-term financing needed, including to support specific supply chain contracts. Consideration of the legal, commercial, financial, environmental, and social requirements of these experienced international sources of capital is needed, as the requirements may differ from local practice. If their expectations are not met, this can undermine the ability to raise financing. Aligning government strategy, policy, and frameworks with Good International Industry Practice (GIIP) and lender requirements can avoid barriers and costly delays for individual projects seeking finance once permitting has been obtained.

Credit Enhancement Instruments

Governments should consider early engagement with credit enhancement providers to prepare the financing of offshore wind. Financial sustainability of the power sector and sound budgeting of the public financial support will be critical for the long-term sustainability of offshore wind for the public and private sectors. Credit enhancement instruments offered by institutions such as the World Bank can help mitigate these risks and can be considered as a prerequisite by lenders if the offtaker's credit risk is regarded as too substantial. These credit enhancement instruments are typically deployed where a country has demonstrated its commitment over time to financial sustainability of the power sector.

Currency Considerations

Careful consideration of offtake tariff currency, indexation, and related protections in view of the local financing capacity is required. A currency mismatch between revenues from a local currency offtake agreement and hard currency financing are common challenges in emerging markets. This is because both procurers and international investors are keen to minimize their exposure to foreign exchange risks in large long-term projects. The risk allocation is determined by the currency of the tariff, whether or not it is indexed to an international hard currency and associated offtake agreement contractual structure. Given the size of offshore wind projects, this risk represents a large potential exposure for either party. This risk can be mitigated by splitting the offtake currency into a proportion of local currency and a proportion of US Dollars [270]. Inflation risk is a material consideration for developers as it can erode earnings over time, and is a particular risk in emerging markets with high inflation.

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67 Development finance institutions (DFIs) are specialized development organizations that are usually majority owned by national governments. DFIs invest in private sector projects in low- and middle-income countries to promote job creation and sustainable economic growth. They apply stringent investment criteria aimed at safeguarding financial sustainability, transparency, and environmental and social accountability. [322]

68 International financial institutions (IFIs) play a major role in the social and economic development programs of nations with developing or transitional economies. This role includes advising on development projects, funding them, and assisting in their implementation. They are characterized by their independence, AAA-credit rating, and broad membership of borrowing and donor countries [323]

69 Export credit agencies (ECAs) offer trade finance and other services to facilitate domestic companies' international exports. Most countries have ECAs that provide loans, loan guarantees, and insurance to help eliminate the uncertainty of exporting to other countries [324].

Most offshore wind projects to date have been financed in hard currency markets. Offtake tariffs, financing and, even construction contracts have been in hard currency. Taiwan was the first offshore wind market to face a local currency challenge, and it required significant effort to put together those financings (see Case Study 4.6). A similar process is currently ongoing in Poland [271]. Many emerging markets are likely to find less capacity and liquidity in their local banking and capital markets than in Europe or Taiwan.

CASE STUDY 4.6: Financing Offshore Wind in Taiwan

Taiwanese Changfang and Xidao offshore wind projects (collectively CFXD) provide valuable examples of challenges and efforts in raising local financing for offshore wind, for example, a 75:25 debt to equity ratio with NT$70 billion (US$2.5 billion) of 18-year debt; NT$76.1 billion (US$2.7 billion) in local currency from 19 banks; and US$236 million from 4 lenders and EUR 75.4 million (US$88.4 million) of Letter of Credit. With NT$49.5 billion (US$1.8 billion) of coverage, ECAs were instrumental in mobilizing local currency and experienced international lenders. Local Taiwan life insurers provided 7.5 percent of NT$30 billion (US$1.1 billion) equity. [272]

Insurance

Governments should consider how to create a regime that gives investors access to insurance from the international insurance and reinsurance markets. In Taiwan, the international reinsurance market was able to extend insurance capacity to this new geography, in collaboration with the local insurance market.

Governments must also work to evolve their own regulations and insurance risk bearing capacities to develop the local insurance sector in a way that meets the needs of equity investors and lenders. For some uninsurable events, such as failure of an export cable or transformer, it is not possible to push all risks to investors as this can make projects unviable [273].

Local risk factors can be addressed better through the collaboration of local and international insurance sectors. Offshore wind insurance will be influenced by local factors in emerging markets. Enhanced natural catastrophe and political or exchange rate risk will affect pricing or capacity available from international insurance markets.

KEY SUCCESS FACTORS

Related to financing for offshore wind, governments should:

a. Carefully consider how their policies and frameworks affect financing for offshore wind projects.
b. Engage with credit enhancement providers to prepare for the financing of offshore wind.
c. Consider the financing implications of offtake tariff currency, indexation, and related protections.
d. Create a regime and environment which gives investors access to insurance from the international insurance and reinsurance markets.

Suggested reading materials are found in appendix A and full references found in appendix B.

5 NEXT STEPS

While this report aims to help government officials recognize the key success factors for the delivery of a successful offshore wind market and to answer many of the important questions that arise, there will be plenty of other questions that are left unanswered. This final chapter provides further input on resources that can help governments on their journey to develop offshore wind.

Further Reading

Appendix A provides a guide to extensive further reading for deeper understanding and evidence regarding key factors for successful development of offshore wind.

Key Sources of Support

- Governments in the WBG client countries can contact their local World Bank counterparts to discuss options for further support, including access to learning materials designed to complement this document, maps of offshore wind technical potential [274], and national offshore wind roadmaps WBG publishes [2].
- The Global Wind Energy Council (GWEC) offers further support, including its offshore wind Market Readiness Assessment Toolkit [157], which shows the areas where government focus is most needed, and offshore wind technical resource maps [275], which show the potential for offshore wind in nearly 100 countries.
- Countries with established offshore wind markets, especially Denmark, Germany, the Netherlands, and the UK are actively supporting a range of governments in emerging markets.
- The IRENA Coalition for Action [276] aims to provide a platform for governments, businesses, and investors to discuss current challenges relating to renewable energy.
- The IRENA Collaborative Framework on Ocean Energy/Offshore Renewables [277] provides a forum for state and non-state actors to have a person-to-person exchange on offshore wind.
- Key global offshore wind players, including those in the Offshore Renewable Energy Action Coalition (OREAC), provide ongoing engagement, challenge, and support.
- Independent wind industry and policy consulting firms can provide detailed support.

Future Industry Developments

The global offshore wind industry is still young, and there will continue to be innovation and changes in technology, the supply chain, and finance. As a generator of low-carbon electricity, offshore wind sits within the wider energy transition ecosystem that also includes transport, heat, and new energy vectors such as hydrogen. New examples of good practice will continue to be shared, and policies and frameworks are bound to evolve over time to address new opportunities and challenges in a rapidly evolving industry. It is critical, therefore, that governments participate actively in finding the best ways forward.

Next Steps

- Governments are encouraged to establish and prioritize a plan for developing a roadmap for offshore wind, based on the principles of:
- Collaboration, both domestically and internationally.
- Competition.
- Robust, transparent, repeatable, flexible, and fair processes.
- A strategic approach, recognizing offshore wind is a rapidly changing industry operating within a global energy transition.

APPENDIX A

RECOMMENDED FURTHER READING

1. Energy Strategy

For a review of the late low strike prices, see:

- Analysis: Record-low price for UK offshore wind cheaper than existing gas plants by 2023 by the Carbon Brief [278]

For approaches assessing different ways to decarbonize energy systems and develop energy strategies, see:

- IEA's landmark study "Net Zero by 2050" [26]
- UK National Grid Future Energy Scenarios [3]
- The 2035 Report—a strategy for 90 percent clean electricity in the US by 2035 [279]
- UK Government 2050 Electricity System Analysis, planning for net zero emission by 2050 [280]
- The Solutions Project—a vision to achieve 100 percent renewable energy with modelling for nearly every country across the globe [281]
- Infrastructure Outlook 2050—a joint study by Gasunie and TenneT on integrated energy infrastructure in the Netherlands and Germany [282]

For relevant energy strategies, see:

- EU Strategy on Offshore Renewable Energy [283]
- Scottish Government's Energy Strategy [284]
- UK Government's Energy White Paper—Powering Our Net Zero Future [43]

For overviews of key considerations for an offshore wind farm, see:

- Guide to an Offshore Wind Farm by BVG Associates [116]
- World Bank Virtual Study Tour, by the World Bank [285]
- ESMAP Going Global: Expanding Offshore Wind to Emerging Markets by the World Bank [274]
- Offshore Wind Handbook by K&L Gates; SNC Lavalin, Atkins [286]
- Offshore Wind Energy: Owner's Workshop Manual by Haynes [287]

For overviews of floating offshore wind, see:

- National Renewable Energy Laboratory's Overview of Floating Offshore Wind video [288]
- The Future of Wind report by IRENA, covering detailed options for international potential wind strategies [289]

For an example of an energy system storage and flexibility plan, see:

- The UK government's Upgrading Our Energy System strategy [290]

For an example study on the temporal variability of offshore wind generation, see:

- A Crown Estate commissioned study for the UK [291]

2. Policy

2.1 Introduction

For examples of visions for offshore wind, see:

- New York State's Offshore Wind Master Plan [34]; and New York State Energy Research and Development Authority's (NYSERDA) Master Plan studies web page [35] for the many supporting studies
- Japan's Offshore Wind Industry Vision [36]

For a series of 50 recommended actions to the G20 countries to support their offshore renewable deployment strategies, see:

- IRENA, Offshore Renewables—An action agenda for development [292]

For a discussion on the balance between cost reduction and local content, and for an example of industry working together to show how it can meet a government vision for cost reduction, see:

- The Japan Cost Reduction Study by the Global Wind Energy Council and Japan Wind Power Association [37]. This led to much increased government-industry collaboration in Japan

For a definition and discussion about measuring of local content, see:

- Methodology for measuring the UK content of UK offshore wind farms by BVG Associates [208]

For examples of government-industry collaboration to build and evolve policy objectives for offshore wind in the UK, see:

- The Crown Estate's Offshore Wind Cost Reduction Pathways Study [38]. This led to a first government-industry offshore wind "deal" in the UK
- The Offshore Wind Cost Reduction Task Force's Report [39] for a report summarizing shared government-industry commitment to delivering cost reduction in offshore wind
- The UK Government's Offshore Wind Sector Deal [40] for information on UK's second government-industry offshore wind "deal"
- Offshore Wind Growth Partnership website [41] for information on industry commitment after the UK's second government-industry offshore wind "deal"
- Offshore Wind Industry Council web page [42]

For examples of strong communication of offshore wind policy drivers, see:

- UK Government's Powering Our Net Zero Future [43]
- WindEurope's article on Poland adopting the historic Offshore Wind Act [45]

For a further background reading on policy options, see:

- IEA RETD's Comparative Analysis of International Offshore Wind Energy Development [293]

2.2 Volume and Timescales

For examples of a volume target to 2040, see:

- An announcement on the German government's website [46]
- Japan's Offshore Wind Industry Vision [36]
- Poland's Energy Policy to 2040 on the Polish Government's website [47]

For an example of regional collaboration to accelerate offshore wind, see:

- The Transnational energy cooperation between North Sea countries [48]

For an example of a long-term regional vision set out by industry, see:

- BVG Associates' Our energy, our future report for WindEurope [49]

For an example of a long-term regional vision set out by governments, see:

- Boosting Offshore Renewable Energy for a Climate Neutral Europe by the European Commission [50]

For information on the United Nations position on ocean sustainability, see:

- Ocean Panel's Ocean Solutions That Benefit People, Nature and the Economy [51]

For an example of a long-term industry vision, also setting out the benefits of offshore wind to countries new to the industry, see:

- The Power of Our Ocean by the Offshore Renewable Energy Action Coalition [7]

For an example of a long-term national vision and roadmap, see:

- World Bank Group: Roadmap for offshore wind in Vietnam by the World Bank Group [2]

Further reading material for section 2.1 is also relevant for volumes and timescales.

2.3 Cost of Energy from Offshore Wind

For examples of cost reduction studies describing how reductions will be achieved, see:

- The Japan Cost Reduction Study by the Global Wind Energy Council and Japan Wind Power Association [37]
- The Crown Estate's Offshore Wind Cost Reduction Pathways Study [38]
- BVG Associates' Offshore wind cost reduction pathways report [56] for detailed information on the technology-related cost of energy reduction
- Cost Reduction Monitoring Framework by the Offshore Renewable Energy Catapult [57]
- Committee on Climate Change's Approaches to cost-reduction in offshore wind report [58]
- International Renewable Energy Agency's Innovation Outlook: Offshore Wind report for an exploration of the innovation landscape in offshore wind [59]
- The InnoEnergy 2017 Future renewable energy costs: offshore wind report for structured analysis of costs and cost reduction opportunities in offshore wind [60]
- The UK Government Department for Business, Energy & Industrial Strategy (BEIS) Energy Innovation Needs Assessment: Offshore wind [61]
- A De Ingenieur article summarizing the analysis performed by the Dutch Court of Auditors [62]

For examples of government cost targets, see:

- In Japan: Japan Wind Power Association's 2nd Council Meeting Report [64]
- In UK: The Crown Estate's Offshore Wind Cost Reduction Pathways Study [38]and Offshore Wind Cost Reduction Task Force's Offshore Wind Cost Reduction Task Force Report [39]

2.4 Local Jobs and Economic Benefits

For a policy document with significant focus on economic benefits, see:

- The UK's Industrial Strategy Offshore Wind Sector Deal [40]

For the latest information on Taiwan's evolving local content policy, see:

- Recharge article: Taiwan's new policy can turn it into a major regional offshore wind hub [65]

For an analysis of local economic benefit from offshore wind in an emerging market, see:

- Roadmap for offshore wind in Vietnam by the World Bank Group [2]

For an exporation of job creation in offshrore wind, see:

- IRENA's Renewable Energy Benefits: Leveraging Local Capacity for Offshore Wind [294]

For examples from the US of public support for local supply chain and skills development, see:

- Maryland Energy Administration's Offshore Wind Workforce Training Program [66] and Capital Expenditure Program [67]
- An offshoreWIND.biz article, New Jersey Okays Almost USD 6 Million for Offshore Wind [68]

For information around diversity and inclusion, see:

- Offshore Wind Industry Council and Scottish Offshore Wind Energy Council for a practical best-practice guide to increasing diversity and inclusion [69]

For an example of national targets set for gender balance in offshore wind, see:

- The UK's Industrial Strategy Offshore Wind Sector Deal [40]

For best practices guidelines for gender diversity in talent recruitment, see:

- GWEC's Best practices [71]

2.5 Environmental and Social Sustainability

For a broad view of sustainability considerations, see:

- United Nations Sustainable Development Goals [83]
- World Resources Institute, High Level Panel for a Sustainable Ocean Economy website [85]

See the Crown Estate's Marine Data Exchange for information on technical data sharing in offshore wind [75]

3. Frameworks

3.1 Organizing Frameworks

For examples of national one-stop shops for offshore wind, covering multiple frameworks, see:

- Danish Energy Agency web page [76]
- Dutch RVO web page [77]

For examples of projects delayed or cancelled due to permitting, see:

- In the US: A Reuters article on the Vineyard Wind project in the US [78]
- In Taiwan: Information on the Guanyin Offshore Wind Farm project [79]

For examples of government-industry collaboration to help develop frameworks, see:

- In Japan: Japan Wind Power Association's 2nd Council Meeting Report [64]
- In the UK: Offshore Wind Industry Council web page [42]
- In the Netherlands: Lessons from a Dutch community of practice [95]

3.2 Marine Spatial Planning

For further big-picture sustainability considerations, see:

- United Nations Sustainable Development Goals [83]
- The Potential of the Blue Economy: Increasing Long-term Benefits of the Sustainable Use of Marine Resources for Small Island Developing States and Coastal Least Developed Countries [84]
- World Resources Institute's High Level Panel for a Sustainable Ocean Economy [85]

For collaboration between countries and examples of MSP, see:

- European MSP Platform website [88]
- Offshore Coalition for Energy and Nature (OCEaN), Memorandum of Understanding [89]
- The Eight Baltic Sea Countries Ink Offshore Wind Pact [90]

For good practices on MSP, see:

- UNESCO's website for much information about MSP [72]
- Consortium including UNESCO: Marine spatial planning: a Step-by-Step Approach [91]
- World Bank Environmental and Social Standards [92]

For an example of regional use of cost of energy mapping to help locate most suitable areas for offshore wind, see:

- BVG Associates' Unleashing Europe's offshore wind potential report [93] and Our energy, our future report [49]

For the legal basis for MSP, see:

- The United Nation's Law of the Sea [96]

3.3 Leasing

For examples of leasing frameworks developed in different countries, see:

- The Netherlands Enterprise Agency's website on Hollandse Kust (noord) Wind Farm Zone, Site V [104]
- The Crown Estate, Offshore Wind Leasing Round 4 web pages [105]
- BOEM's website for upcoming leases and roadmap to gain a lease [106]

For an export system leasing consideration, see:

- The Crown Estate, Export transmission cables for offshore renewable installations—Energy and Infrastructure Policies, Procedures and Guidelines [107]

For more information on BOEM and its processes, see:

- The BOEM website [108]
- BOEM National and Regional Guidelines for Renewable Energy Activities web page [109]

For good examples of communication about leasing, see:

- The Crown Estate, Offshore Wind Leasing Round 4 web pages [105]
- The Crown Estate Offshore Wind Leasing Round 4: Bidders Information Day—Morning Session [103]

For recent leasing frameworks and guidance developed for the US offshore wind market:

- The Bureau of Ocean Energy Management's (BOEM) website [108]
- BOEM's National and Regional Guidelines for Renewable Energy Activities web page for the US [109]
- The Crown Estate's Information Memorandum: Introducing Offshore Wind Leasing Round 4 for the frameworks in the UK, including requirements on developers to keep development progressing [110]

See the Crown Estate's Marine Data Exchange for information on technical data sharing in offshore wind [75]

See G+ Global Offshore Wind Health & Safety Organisation for health and safety statistics [114]

For decommissioning considerations, see:

- UK Government, Decommissioning of Offshore Renewable Energy Installations Under the Energy Act 2004; Guidance Notes for Industry (England and Wales) [115]

3.4 Permitting

For a typical view of project development costs, see:

- BVG Associates' Guide to an Offshore Wind Farm report [116] or Wind farm costs page of website [117]

For examples of good practice for administering permitting, see:

- Planning Inspectorate, National Infrastructure Planning web page [119]
- Planning Inspectorate Legislation and advice web page [121]
- BOEM's National and Regional Guidelines for Renewable Energy Activities web page for the US [109]

For a discussion about how to provide design and purchasing flexibility at the permitting stage, see:

- The Planning Inspectorate's Using the Rochdale Envelope web page [122]

For World Bank Group environmental and social standards, which are usually adopted by international lenders, see:

- World Bank Environmental and Social Standards [92]
- IFC Performance Standards [123]

For a discussion on local public attitudes and visual considerations, see:

- Maarten Wolsink's paper: Wind power implementation: The nature of public attitudes: Equity and fairness instead of "backyard motives" [127]

For a comprehensive overview on the Impacts and mitigations of wind projects, including offshore wind, see:

- A book by M. Perrow, *Wildlife and Wind Farms, Conflicts and Solutions* [295]

For backgrounds on Cape Wind's offshore wind permitting journey, see:

- The J. Levitz article, Cape Cod Wind Farm Tiptoes Ahead [128]
- A journal article focusing on regulatory uncertainty by Nathanael Hartland [129]
- A *Forbes article on Willian I Koch's involvement* [130]

For more successful, recent permitting journeys, see:

- Bureau of Ocean Energy Management, Vineyard Wind web page [131]
- Federal Infrastructure Permitting Dashboard for Vineyard Wind [132]

For a discussion of best practice in stakeholder engagement in offshore wind, see:

- International Finance Corporation, Local Benefit Sharing in Large-Scale Wind and Solar Projects [133]

3.5 Offtake and Revenue

For examples of different processes to award offtake agreements, see:

- The Netherlands Enterprise Agency's website on Hollandse Kust (noord) Wind Farm Zone, Site V [104]
- New York State Energy Research and Development Authority (NYSERDA), 2020 Offshore Wind Solicitation (Closed) web page [138]
- UK Government Department for Business, Energy & Industrial Strategy (BEIS), Policy paper: Contracts for Difference [140]
- National Grid ESO, CfD Process [141]

For details of an interim process to award offtake agreements, see:

- UK Government Final Investment Decision Enabling for Renewables web page [136]
- UK government's Implementing Electricity Market Reform (EMR) paper [137]

For commentaries on the design of competitive auction processes for renewable energy, see:

- World Bank—Electricity Auctions: An Overview of Efficient Practices [296]
- IRENA "Renewable Energy Auctions: A Guide to Design" [297]

For a discussion of fiscal support, see:

- KPMG, The Power of nature: taxation of wind power [135]

For discussions on the bankability of offtake agreements and an example power purchase contract, see:

- US International Development Finance Corporation, Important Features of Bankable Power Purchase Agreements for Renewable Energy Power Projects [148]
- Nstar Electric, "Offshore wind generation unit PPA" [149]
- Inter-American Development Bank "Guide for Designing Contracts for Renewable Energy Procured by Auctions" [298]

For information on early Corporate PPAs (CPPAs) in offshore wind, see:

- Northland Power, Corporate Renewable PPAs [150]
- Ørsted, Ørsted and Amazon sign Europe's largest offshore wind corporate power purchase agreement [151]

Further reading material for section 2.1 is also relevant.

3.6 Export System and Grid Connection

For lessons learned and best practice from mature markets, see:

- A detailed guidance note on lessons learned from the European wind market in offshore transmission, developed for the US market but useful as a primer for other markets, by the New York Power Authority [299]
- Offshore wind transmission study comparison of options, prepared for New Jersey Board of Public Utilities [163]

For key details and further case studies surrounding grid integration, see:

- The Green Giraffe's Offshore Wind Transmission, US presentation [170]

For an example of consultation contributing to a grid integration policy for offshore wind, see:

- The Offshore Wind: Consultation to Inform a Grid Development Policy for Offshore Wind in Ireland report by the Irish Government [300]

For information on grid integration as part of a future vision for offshore wind, see:

- IRENA's Future of wind: Deployment, investment, technology, grid integration and socio-economic aspects report [289]

3.7 Health and Safety

For examples of standards on health and safety that are internationally recognized, see:

- The GWO's Basic Safety Training Standard [172]
- The Global Offshore Wind Health and Safety Organisation Good Practice Guidelines [173]
- Renewable UK's Offshore Wind and Marine Energy Health and Safety Guidelines [301]
- The World Bank Group's Environmental, Health, and Safety Guidelines for Wind Energy [302]
- The World Bank Group's Environmental, Health, and Safety (EHS) Guidelines cover both health and safety as well as environmental considerations [171]
- The World Bank's Environmental, health, and safety guidelines for offshore oil and gas development [303]
- World Bank's Environmental, Health, and Safety Guidelines for Ports, Harbors, and Terminals [304]

For an example of improving local industry's health and safety standards, see:

- The GWO's Training Agreement in New Jersey [176]

For recent statistics on health and safety in offshore wind, see:

- The Global Offshore Wind Report 2020 by the Global Wind Energy Council [174]

For a study of health and safety at a regional level in the offshore wind industry, with lessons learned, see:

- NYSERDA's New York State Offshore Wind Master Plan Health and Safety Study [180]

For a review of the UK's Health and Safety at Work Act see:

- An article analyzing the effectiveness of the Act by Kizzy Augustin [179]

3.8 Certification

For information of international best practice relating to certification and standards, see:

- The International Renewable Energy Agency's Nurturing offshore wind markets: Good practices for international standardization [305]

For a summary of good practices reacting to international standardization and a recommendation for policy makers see:

- The International Renewable Energy Agency's Good practices for international standardization has a summary of the technical standards and a recommendation for standardization for policy makers [294]

For guidance notes and reviews of certifications, see:

- Lloyds Register's Guidance Notes for Offshore Wind Farm Project Certification, useful as one of the key certifiers in the offshore wind industries [306]
- Mapping of Offshore Wind Industry Standards Project No. 2016–080, a report by Danish Energy for a review of the standards present in the offshore wind industry [307]

For details of wind turbine design certification, see:

- IEC 61400–22 Wind turbines—Part 22: Conformity testing and certification for the International Standard that defines rules and procedures for a certification system for wind turbines that comprises both type certification and certification of wind turbine projects installed on land or off-shore [308]

4. Delivery

4.1 Supply Chain

For examples of public funding to support private investment, see:

- UK Government Department for Business, Energy & Industrial Strategy (BEIS), Offshore Wind Manufacturing Investment Scheme Major Portside Hubs: Guidance [188]
- The National Offshore Wind Research & Development Consortium (NOWRDC)'s website for an example of a funded program of cost reduction in offshore wind [189]
- New Jersey Economic Development Authority, Offshore wind tax credit: ERA update [190]

For examples of establishing national offshore wind innovation needs, see:

- ADEME's report [236]
- UK Government Department for Business, Energy & Industrial Strategy (BEIS) Energy Innovation Needs Assessment: Offshore wind [61]

For examples of support mechanisms and supporting research and technology organizations, see:

- The National Offshore Wind Research & Development Consortium (NOWRDC)'s website for an example of a funded program of cost reduction in offshore wind [189]
- The Carbon Trust's Offshore Wind Accelerator (OWA) web page for an example of joint industry projects in offshore wind [237]
- Danish Technical University, web page [238]
- Fraunhofer Institute for Wind Energy Systems, web page [239]
- National Renewable Energy Laboratory, Offshore Wind Research web page [240]

- Offshore Renewable Energy Catapult, web page [241]
- Innovate UK and Offshore Renewable Energy Catapult, Offshore Wind Innovation Hub: What We Do [242]

For examples of workshop test facilities specific to offshore wind, see:

- Clemson University, regarding wind turbine drivetrain testing [243]
- Fraunhofer Institute for Wind Energy Systems, regarding wind turbine blade bearing testing [244]
- Offshore Renewable Energy Catapult regarding wind turbine blade testing [245]

For examples of projects seeking to reduce the carbon Intensity of offshore wind, see:

- Hybrit, Fossil free steel website [247]
- Composites World, DecomBlades consortium awarded funding for a cross-sector wind turbine blade recycling project [248]
- National Composites Centre, SusWIND web page [249]
- LM Wind Power, “ZEBRA project” launched to develop first 100 percent recyclable wind turbine blades [250]

For discussions of local industrial clusters in ports, see:

- World Bank Port Reform Toolkit [191]
- Information about Esbjerg port,Denmark [192] [193]

For examples of supply chain gap analyses, see:

- Offshore Wind: A 2013 supply chain health check report for a review of the existing supply chains of the time [196]
- East of England Energy Zone, Offshore Wind Supply Chain Capability Matrix [197]
- UK offshore wind supply chain: capabilities and opportunities (2014) [198]
- Offshore Wind Industry Council, The UK Offshore Wind Industry: Supply Chain Review [199]

For information on industry commitment after the UK’s second government-industry offshore wind “deal”, see:

- Offshore Wind Energy Council partnership website [41]

For an example of a single industry player supporting its own incubation program, see:

- offshoreWIND,biz, Ørsted Funds Offshore Wind Supply Chain Development in Taiwan [200]

For examples of good communication of industry opportunities, see:

- Business Network Offshore Wind, Market Dashboard [201]
- RenewableUK, Project Intelligence [202]
- Norwigan Energy Partners (NORWEP), web page [203]
- NOF web page [204]
- Oil & Gas GUK, Share fairs [205]

For examples of a public supply chain database and details of a prequalification database, see:

- Scottish Enterprise, Scottish Offshore Wind Supply Chain Directory [206]
- Achilles, UVDB Community [207]
- NOF, Supply Chain Directory [309]
- BVG Associates’ Guide to an Offshore Wind Farm report [116] or Supply Chain Maps section of website [310]

For examples of local content measurement by percentage, see:

- Methodology for measuring the UK content of UK offshore wind farms, for an example of government and industry-accepted method of assessing local content [208]
- In Japan: Japan Wind Power Association's 2nd Council Meeting Report [64]
- Dentons article on offshore wind in Poland [209]
- The Offshore Wind Program Board's report: The UK content of operating offshore wind farms [211]
- RenewableUK's Offshore Wind Industry Investment in the UK: 2017 Report on Offshore Wind UK Content [210]

For information on UK's process for encouraging local economic benefit, see:

- BEIS' website Contracts for Difference (CfD) Allocation Round 3: Supply Chain Plan guidance web page [212]

For an example of Supply Chain Plans approved by the UK government before its 2019 revenue support auctions, see:

- BEIS' webpage Contracts for Difference 3rd allocation round: Supply Chain Plans web page [213]
- For an example of generic contracting terms used in offshore wind, see:
- FIDIC web page [214], Oil & Gas UK, LOGIC web page [215], and NEC, About NEC web page [216]
- For examples of skills studies and career opportunity assessments, see:
- BVG Associates, Job Roles in Offshore Wind [217]
- New York State Energy Research and Development Authority (NYSERDA), The Workforce Opportunity of Offshore Wind in New York [218]
- BVG Associates, The Virginia advantage: The roadmap for the offshore wind supply chain in Virginia [219]
- BVG Associates, U.S. Job Creation in Offshore Wind [220]

For examples of skills development programmes, see:

- East of England Offshore Wind Skills Centre, web page [221]
- An offshoreWIND.biz article, Ørsted Taiwan Sends First WTG Technicians for Training in UK [222]

For a consideration on how to accelerate equality and diversity, see:

- Supergen Offshore Renewable Energy Hub; Aura, Equality, Diversity and Inclusion in Engineering—A Roadmap Towards a Positive Change [224]

For examples of initiatives to raise knowledge across the industry, see

- The Crown Estate's Marine Data Exchange for information on technical data sharing in offshore wind [75]
- Offshore Renewable Energy Catapult, SPARTA—System Performance, Availability and Reliability Trend Analysis, [225]
- FINO1,2,3, FINO—Research platforms in the North Sea and Baltic Sea, [226]

For more information on cabotage in different markets, see:

- Investopedia, The Jones Act [233]
- Bundesministerium der Justiz und für Verbraucherschutz, Schiffssicherheitsverordnung (in German) [234]
- Baker McKenzie presentation Outlook for the Japanese Offshore Wind Market [235]

4.2 Ports

For examples of existing port summaries in different countries, see:

- Ports for Offshore Wind by the Crown Estate Scotland [251]
- Port Planning & Investment Toolkit report by a consortium for the US [258]
- Supply chain, port infrastructure and logistics study for offshore wind farm development in Gujarat and Tamil Nadu, for a study in India by the Global Wind Energy Council [259]
- Offshore Wind Port Feasibility Study of Taiwan by various authors [260]
- New York State Offshore Wind Master Plan Assessment of Ports and Infrastructure by NYSERDA [311]

For an overview of a plan to start a consortium of ports in Europe for the offshore wind industry, see:

- A statement from the offshore wind ports by WindEurope [261]

For a study on the effect of maritime subsidies, see:

- The International Transport Forum's Maritime Subsidies Do They Provide Value for Money? Recommendations are also provided on improving the value for money achieved by any subsidies [262]

For an example of the opportunities that may be available for an existing port in offshore wind, see:

- BVG Associates' Offshore wind opportunities in the Port of Lowestoft an independent report for Associated British Ports [312]

For an overview of the key issues around free ports, see:

- CMS-Lawnow's website [263]

For lessons learned around Special Economic Zones, see:

- The World Bank's report: Special Economic Zones Performance, lessons learned, and implications for zone development [264]

For guidance on the state of play of floating wind, including the main differences and similarities between floating platforms, see:

- WindEurope's Report: Ports: a key enabler for the floating offshore wind sector [313]

4.3 Transmission Network

For a detailed review into offshore transmission and grid connections in Europe, see:

- Connecting Offshore Wind Farms by Navigant [158]

For a study on market design for an efficient transmission of offshore wind energy, see:

- The study by the German Institute for Economic Research (DIW ECON) [314]

For a more detailed guidance for offshore transmission and grid connections for the US market, see:

- The Business Network for Offshore Wind [315]

For lessons learned within offshore electrical transmission, see:

- The Crown Estate's Sharing lessons learned and good practice in offshore transmission report [316]

4.4 Financing

For further information on the Europe market, see:

- WindEurope's Financing and investment trends: The European wind industry in 2019 report [317]

For an overview of the funding for offshore wind in Europe, see:

- The European Wind Energy Association's report: Where's the money coming from? Financing offshore wind farms [318]

For an example of financing in an emerging economy, see:

- The Financing Offshore Wind in Taiwan report [319]

For a useful overview of risk in the sector, see:

- See Grant Thornton's Winds of change: Navigating risk in the offshore wind sector report [320]

APPENDIX B

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APPENDIX C
ABBREVIATIONS

Term	Description
BEIS	Business, Energy and Industrial Strategy (UK Government department)
BOEM	Bureau of Ocean Energy Management
CAPEX	capital expenditure (including DEVEX, up to start of project operation)
CfD	contract for difference
CHA	critical habitat assessment
CIF	Climate Investment Fund
CPPA	Corporate Power Purchase Agreement
CTV	crew transfer vessels
DECEX	decommissioning expenditure (after the end of project operation)
DEVEX	development expenditure (prior to project construction)
DFI	development finance institutions
ECA	export credit agencies
EEZ	Exclusive Economic Zone
EMR	Electricity Market Reform
EPA	Environmental Protection Administration
ESIA	environmental and social impact assessment
ESMAP	Energy Sector Management Assistance Program
ESS	Environmental and Social Standards
EU	European Union
FID	Final investment decision
FIDER	Final Investment Decision Enabling for Renewables
FIDIC	International Federation of Consulting Engineers
FIT	feed-in tariff
FTE	full-time equivalent
G+	G+ Offshore Wind Health and Safety Association
G7	Group of Seven (an organization made up of the world's 7 largest economies—United States, United Kingdom, Canada, France, Germany, Italy, Japan, European Union)
GCF	Green Climate Fund
GIIP	Good International Industry Practice
GVA	gross value added

Term	Description
GW	gigawatt, a unit of power
GWEC	Global Wind Energy Council
GWh	gigawatt-hour, a unit of energy
GWO	Global Wind Organization
H&S	health and safety
HSE	UK's Health and Safety Executive
HVDC	high voltage direct current
IEA	International Energy Agency
IEA RETD	International Energy Agency—Renewable Energy Technology Department
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
IFC PS	International Finance Corporation's Performance Standards
IFI	international financial institutions
IOC	Intergovernmental Oceanographic Commission
IRENA	International Renewable Energy Agency
IRR	internal rate of return
ISO	International Organization for Standardization
ITC	investment tax credits
LAT	lowest astronomical tide
LCOE	levelized cost of energy
LOGIC	Leading Oil and Gas Industry Competitiveness
MoU	memorandum of understanding
MSP	marine spatial planning
MW	megawatt, a unit of power
MWh	megawatt-hour, a unit of energy
NEC	new engineering contract
NGO	nongovernmental organization
NJEDA	New Jersey Economic Development Authority
NYSERDA	New York State Energy Research and Development Authority
O&M	operation and maintenance
OCS	outer continental shelf
OFGEM	UK Office of Gas and Electricity Markets
OFTO	offshore transmission owner
OPEX	operation expenditure (during project)
OREAC	Offshore Renewable Energy Action Coalition

Term	Description
OSHA	Taiwan's Occupational Safety and Health Administration
OWIC	Offshore Wind Industry Council
PINS	Planning Inspectorate—executive agency of the United Kingdom government
PRI	Principles for Responsible Investment
PTC	production tax credits
QHSE	Quality, Health, Safety and Environment
R&D	research and development
REC	renewable energy certificate
RPS	renewable portfolio standard
RTO	research and technology organizations
RVO	Rijksdienst voor Ondernemend Nederland (Netherlands Enterprise Agency)
SBTI	Science Based Targets Initiative
SOE	state-owned enterprises
SOV	service operation vessels
SOWEC	Scottish Offshore Wind Energy Council
SPARTA	System Performance Availability and Reliability Trend Analysis
UNCLOS	United Nations Convention on the Law of the Sea
UNEP-FI	United Nations Environmental Programme Finance Initiative
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNSDG	United Nations Sustainable Development Goals
WACC	weighted average cost of capital (quoted in this document in real terms)
WBG	World Bank Group