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MAKING OFFSHORE WIND WORK

Key Factors for Successful Development of Offshore Wind in Emerging Markets

REPORT

WORLD BANK GROUP
THE WORLD BANK IBRD • IDA
IFC International Finance Corporation
ESMAP Energy Sector Management Assistance Program

April 2025

ABOUT ESMAP

The Energy Sector Management Assistance Program (ESMAP) is a partnership between the World Bank and over 20 partners that helps low- and middle-income countries reduce poverty and boost growth through sustainable energy solutions. ESMAP's analytical and advisory services are fully integrated within the World Bank's country financing and policy dialogue in the energy sector. Through the World Bank Group (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 shape WBG strategies and programs to achieve the WBG Climate Change Action Plan targets. Learn more at: https://esmap.org.

Production Credits

The paper was developed as part of the World Bank Group's Offshore Wind Development Program, jointly led by the Energy Sector Management Assistance Program (ESMAP) and the International Finance Corporation (IFC), which aims to accelerate offshore wind development in emerging markets. For more, please see: www.esmap.org/ offshore-wind.

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This update to the original report was led by Huub den Rooijen (Advisor) and Gregory Scopelitis (Advisor) with support from BVG Associates (BVGA) and Arup. The team would like to recognize the dedication and hard work of Leo Bertels (BVGA) and Bruce Valpy (BVGA). The original report was published in 2021 by the WBG's Offshore Wind Development Program with support from the same consultancies. A special thank you goes to Sean Whittaker (IFC/ESMAP) for leading the Program through this effort, and to Rafael Ben and Jenny Hasselsten (WBG) for their support.

This publication has brought together a deep wealth of offshore wind expertise and experience with invaluable contributions from the entire WBG Offshore Wind Development Program team, emerging market governments, donor governments, industry participants and partner organizations supporting offshore wind around the world.

Thank you to all involved in creating the original Key Factors report which was published in 2021. This update would not have been possible without the insight and thoughtful feedback from Arturo Pulido (Colombian Ministry of Mines and Energy), Gustavo Ponte (Brazil Energy Research Office), Dr. Pramir Kumar Dash (India's Ministry for New and Renewable Energy), Richard Burch (UK Department of Business and Trade), Anders Ystad and Morten Dillner (Equinor), Jens Orfelt (RWE), Adriano Gouveia (Neoenergia), Aaron Smith (Principle Power), Wadia Fruergaard (Vestas), Hendrik Engelmann and Andreas Heinz (European Investment Bank), Rebecca Williams (GWEC), Peter Burston, Aonghais Cook and Ben Jobson (The Biodiversity Consultancy), and Mattia Cecchinato (WindEurope).

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FOREWORD — WORLD BANK GROUP

WHY THE GLOBAL ROLLOUT OF OFFSHORE WIND POWER MATTERS

Offshore wind is integral to scaling up the world's clean energy transition, especially across emerging markets in Asia, Latin America and Africa.

Experience from established markets in Europe and China demonstrates that offshore wind power is a proven form of reliable, large-scale energy generation with long-term trends of cost reduction.[1]

Today's offshore wind farms supply millions of citizens and businesses with homegrown renewable electricity. The wind industry has a track record which supports economic growth, enhances energy security, and creates new jobs — while protecting and restoring ecosystems.

In the future, innovations in smart operations, green hydrogen and floating turbines will further enhance offshore wind's central role in sustainable and resilient energy systems.

A pivotal phase for offshore wind in emerging markets

As a large-scale, cost-competitive generation technology, the expansion of offshore wind across emerging markets charts a pathway for low-carbon and resilient development, as outlined in the World Bank Group's Climate Change Action Plan.[2]

'Key Factors for Successful Development of Offshore Wind in Emerging Markets' is designed as a guide for countries who are committed to delivering offshore wind at scale as part of their energy mix. It aims to help governments with favourable offshore wind resources establish the policies, processes, and regulatory frameworks that best suit their local, national and regional contexts.

The first edition of this report in 2021 was a seminal publication of the World Bank Group's Offshore Wind Development Program, jointly led by the Energy Sector Management Assistance Program (ESMAP) and the International Finance Corporation (IFC) to accelerate the uptake of offshore wind in emerging markets.

This updated edition comes at a pivotal moment. Global action must be galvanized and reinvigorated to meet the growing energy needs of new markets. Time is ticking to fulfil the world's pledge to triple renewable energy by 2030.[3]

We do not underestimate the scale of the task. For governments, there is no doubt that establishing and sustaining an offshore wind industry can be daunting; it is a complex and capital-intensive undertaking with considerable infrastructure demands. At the same time,

1 As illustrated by Figure 2.7: Recent Cost of Energy Reduction Trajectory in Established Markets

2 Climate Action Plan 2021-25

3 Pledge announced at COP28

industry faces pressures of turbulent macroeconomics, supply chain disruptions and social acceptability.

Against this backdrop, it is important for governments in emerging markets to create an environment that attracts industry and investment, leading to international-standard projects that spur economic development and meet growing demand for clean, cost-competitive electricity.

This comprehensive report is informed by lessons learnt through the course of over 20 years of offshore wind development. We are grateful for the valuable contributions from industry, policy makers and communities who have helped compile the international best practices and technological advancements of the sector. This edition includes updates on key topics such as marine spatial planning; integrated environmental & social sensitivity mapping; mobilizing finance; and the innovative applications of AI to improve wind farm design and operations.

The story so far: the World Bank Group's Offshore Wind Development Program

Since launching in 2019, the Offshore Wind Development Program has supported 26 client countries[4] with technical assistance to assess their offshore wind potential.

The Program's team, consisting of World Bank Group staff and expert offshore wind advisors, act as connectors, data gatherers, analysts, and expert knowledge brokers, collaborating closely with client governments, businesses and local stakeholders to lay the groundwork for a long-term pipeline of bankable projects.

To date, nine country 'Roadmaps' have been developed along with a series of global studies to help new markets de-risk projects and meet international lenders' requirements.[5] Tangible progress is evident with offshore wind now firmly established in the national energy plans of World Bank Group client countries including Brazil, Colombia, Philippines, Romania and Vietnam. In just five years, targets and project proposals for offshore wind across 11 countries have increased from 0 to over 500 GW.

The hard work lies ahead. The World Bank Group stands ready with its partners to help propel emerging offshore wind markets to success.

Dr. Demetrios Papathanasiou
GLOBAL DIRECTOR FOR THE WORLD BANK'S ENERGY AND EXTRACTIVES GLOBAL PRACTICE

4 ESMAP Annual Report 2024

5 Roadmaps have been developed for Vietnam (2021), Azerbaijan (2022), Colombia (2022), Philippines (2022), Sri Lanka (2023), Brazil (2024), Romania (2024), Türkiye (2024) and South Africa (2025).

FOREWORD — GLOBAL WIND ENERGY COUNCIL

Offshore wind has achieved impressive success in establishing itself as a transformative technology. It has a solid track record of providing clean power at a large-scale, keeping the lights on for millions of homes and businesses across Europe and Asia. The offshore wind sector has brought meaningful and significant regional economic growth and positive impacts to communities that had been left behind during post-industrial decline.[6] Where it has been built at scale, we have seen costs reduce significantly in a short space of time, to become competitive with fossil fuel and nuclear generation.[7]

Our data at GWEC shows firmly that the growth of offshore wind is now so much more than simply a North Sea or Chinese success story, with signs of progress around the world. In 2023, despite macro-economic challenges in key markets, the offshore wind sector achieved impressive growth, installing 10.8 GW of new capacity, bringing the global total to 75.2 GW. As the world enters the "Age of Electricity",[8] countries around the world are looking to build the next stage of their economic growth and resilience using renewables. Offshore wind, with its high capacity factors and strong availability, is well suited to adding large amounts of zero carbon power, reducing dependence on volatile fossil fuel prices. We are now seeing governments choose offshore wind as a way to significantly enhance their energy security and resilience.

This means that an increasingly diversified set of countries are seeking to make their offshore wind ambitions a reality. Indeed, government membership of the Global Offshore Wind Alliance, a diplomatic, multi-stakeholder initiative on offshore wind, has grown to more than 27 governments, all looking for support to move their offshore wind efforts ahead. The World Bank ESMAP-IFC offshore wind development program, in collaboration with GWEC and other partners, has played an important role in supporting many of these markets to plan and prepare for their offshore wind growth. Quickly after its launch, the first edition of the Key Factors report became an indispensable guide for those embarking upon their first forays into offshore wind, supporting a new wave of countries pursuing offshore wind at scale. GWEC's analysis now shows a suite of markets that were, until recently, considered to be 'emerging markets' now moving successfully further along their offshore wind pathway.

For example, in the last few months, we have seen the passage of the Brazilian Offshore Wind Bill, the Philippines set dates for its first auction, Colombia open their first offshore wind tender, and Vietnam begin to lay the detailed auction regulations for offshore wind. In East Asia, we have also seen the momentous passage of the 'Offshore Wind One Stop Shop' Bill in Korea, and in Japan the recent Round 3 auction results and re-tabling of the EEZ Bill in the National Diet. In Australia, feasibility licenses have been issued across Victoria and New South Wales.

6 For example, see 'Economic Impact Study of Ørsted Investments in the Humber region (May 2022)' https://cdn.orsted.com/-/media/www/docs/corp/uk/hornsea-project-two/rsted-economic-impact-in-humber---may-2022---v9.pdf?rev=bb86b69faa1745398ec5579e812f51fe&hash=1AD6593E223BD3BFA7998FFAC321A8D8

7 https://about.bnef.com/blog/global-cost-of-renewables-to-continue-falling-in-2025-as-china-extends-manufacturing-lead-bloombergnef/

8 International Energy Agency 2025

However, the growth of offshore wind has not been without its challenges. The industry continues to face regional disparities in expansion, and inconsistent policy frameworks, such as poor auction design, and protracted permitting regimes, that threaten its ability to scale effectively. And we are now seeing the growth of disinformation and negative messaging, aimed at undermining the key positive arguments for offshore wind.

Where offshore wind has been achieved at speed and scale, it has been a joint effort between governments, industry and investors, to get the risk-reward ratio right. While offshore wind has faced headwinds over the last year, the worst of these macro-economic impacts now appear to be behind us, and policymakers are increasingly attuned to market conditions and are actively crafting solutions which share risks and spread rewards.

In mature markets like the UK, Germany and China, offshore wind continues to demonstrate strong cost competitiveness relative to other energy technologies. Although the sector remains capital-intensive and sensitive to economic fluctuations, emerging APAC markets are poised to replicate the cost reduction trajectories seen in more established regions. This will be driven by expanding installed capacity, economies of scale, enhanced supply chain efficiencies, and the implementation of supportive regulatory frameworks, all of which will play a pivotal role in sustaining the industry's growth and resilience. This Key Factors report is a highly useful tool to achieve and shape these frameworks to enable a thriving offshore wind industry.

Rebecca Williams
DEPUTY CEO, GWEC

EXECUTIVE SUMMARY

Photo credit: Vestas

This report distils experiences from established offshore wind markets into key success factors to help emerging markets build successful offshore wind sectors. It is designed to share international good practice while recognizing the unique contexts of each country. The key factors described here are, therefore, directional rather than prescriptive.

This resource has been developed for government officials and stakeholders in low- and middle-income countries. However, many of the issues and key factors are equally applicable to other countries.

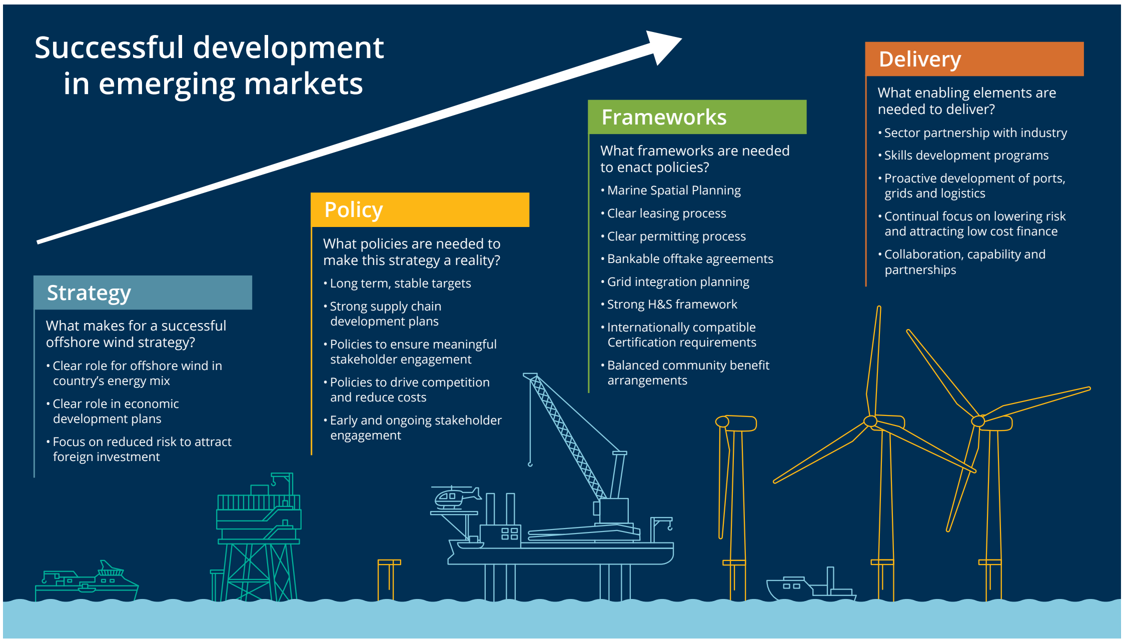
Any country interested in exploiting its offshore wind energy resources needs to answer the fundamental question "*should we develop offshore wind?*" The answer to this question will vary from one country to another, depending on the country's priorities and the feasibility and viability of offshore wind in that country. Before embarking on a journey towards offshore wind deployment, it is important for governments to consider how offshore wind could fit into the country's long-term energy strategy. Separate guidance on the topic of feasibility is available.

The development of an offshore wind sector relies on many different stakeholders playing important and complementary roles; from politicians setting out strategies to port owners planning new facilities. As such, the report highlights information relevant to each stakeholder group while also providing a holistic understanding of how the different parts are woven into the big picture.

THE FOUR PILLARS

This report presents four pillars which act as the foundations for successful offshore wind markets: **Strategy**, **Policy**, **Frameworks** and **Delivery** [illustrated in Figure IN.1.1].

Each pillar includes multiple elements and key success factors. These pillars are linked and together progressively refine the feasibility, viability and deliverability of offshore wind in a market. 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.



STRATEGY

Strategy determines the strategic relevance and long-term planning to develop offshore wind as part of the future energy mix. 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.

Strategy is usually established by politicians, decision makers, and energy planners who understand the role that offshore wind can play in the country's economy and society.

Key Factors for success:

- Technical and economic feasibility of offshore wind and the potential fit of this technology in the country's energy system.
- Country-specific strategic objectives in the pursuit of offshore wind, which can include energy security, energy transition, addressing climate and environmental objectives, industrialization and employment externalities, export, investment stimulations and more.

POLICY

Refers to the underlying political ambitions, laws, and agreements that will turn the strategy into reality. A long-term vision for offshore wind and relevant policies will enhance market confidence and inform government priorities for the creation of frameworks and delivery support initiatives. These policies aim to define the priorities and settle the trade-offs between potentially conflicting elements of the strategy.

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.

Policies are usually created and implemented by lawmakers and officials.

Key Factors for success:

- **Volume and timescales.** Provide 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.** Secure economic benefits while supporting industry growth.
- **Environmental and social sustainability.** Avoid and minimize impacts on the environment and biodiversity, other sea users, and local communities, while capitalizing on the environmental and social benefits of offshore wind.
- **Stakeholder Engagement.** Undertake dialogue with the public, relevant bodies and industry to provide forward visibility of plans, gather feedback and build consensus.

FRAMEWORKS

Frameworks are the mechanisms through which the policies are enacted. Frameworks, based on policy statements, provide a clear route for offshore wind projects to be developed, constructed and operated.

Frameworks are usually implemented by government agencies and utilities.

Key Factors for success:

- **Organizing frameworks.** Ensure coordination for an efficient and cost-effective project implementation.
- **Marine spatial planning.** Enable larger volumes of offshore wind to be sited in the most environmentally, socially, and commercially appropriate locations.
- **Seabed access rights.** Provide project developers exclusive rights to survey the sites on which to then construct and operate offshore wind projects.
- **Permitting.** Provide project developers permission to construct and operate offshore wind projects that are deemed to be acceptable.
- **Revenue and offtake.** Ensure revenue streams are attractive enough to enable investment decisions in offshore wind projects, typically through long-term bankable offtake arrangements.
- **Export system and grid connection.** Ensure transmission networks can accommodate offshore wind.
- **Health and safety.** Minimize workplace risks and protecting onshore and offshore workers.
- **Standards and certification.** Manage risk through standardization and certification to international standards.
- **Public engagement.** Maintain dialogue at a national and local level to earn public support especially from affected communities and industries.

DELIVERY

Finally, Delivery refers to the enabling environment required to deliver offshore wind projects.

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.

- Maintaining a long-term view on what will be needed to accommodate future offshore wind deployment is critical for associated infrastructure which requires a long lead time such as transmission and ports.

Delivery is implemented by governments in partnership with industry, civil society and other stakeholders.

Key Factors for success:

- **Supply chain.** Enable local jobs and value creation through the supply of components and services to offshore wind projects.
- **Ports.** Unlock investments to support efficient project delivery.
- **Transmission network.** Ensure the transmission network is developed to be ready for offshore wind and other generation capacity.
- **Financing.** Address risk to enable sufficient volume of low-cost finance to support offshore wind. This includes managing risks relating to environmental and social considerations, as well as economic risks in alignment with international lender expectations.

Taken together, these key factors will assist emerging markets to accelerate the time it takes to develop a successful and sustainable offshore wind sector.

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 accelerates 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 continues to undertake 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 identify key considerations in the decision to pursue offshore wind and answer the question "*how do we 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, descriptions of good practice, 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 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.

This 2025 revision integrates industry developments and emerging best practice from the Offshore Wind Development Program's first five years. This includes revisions to content on:

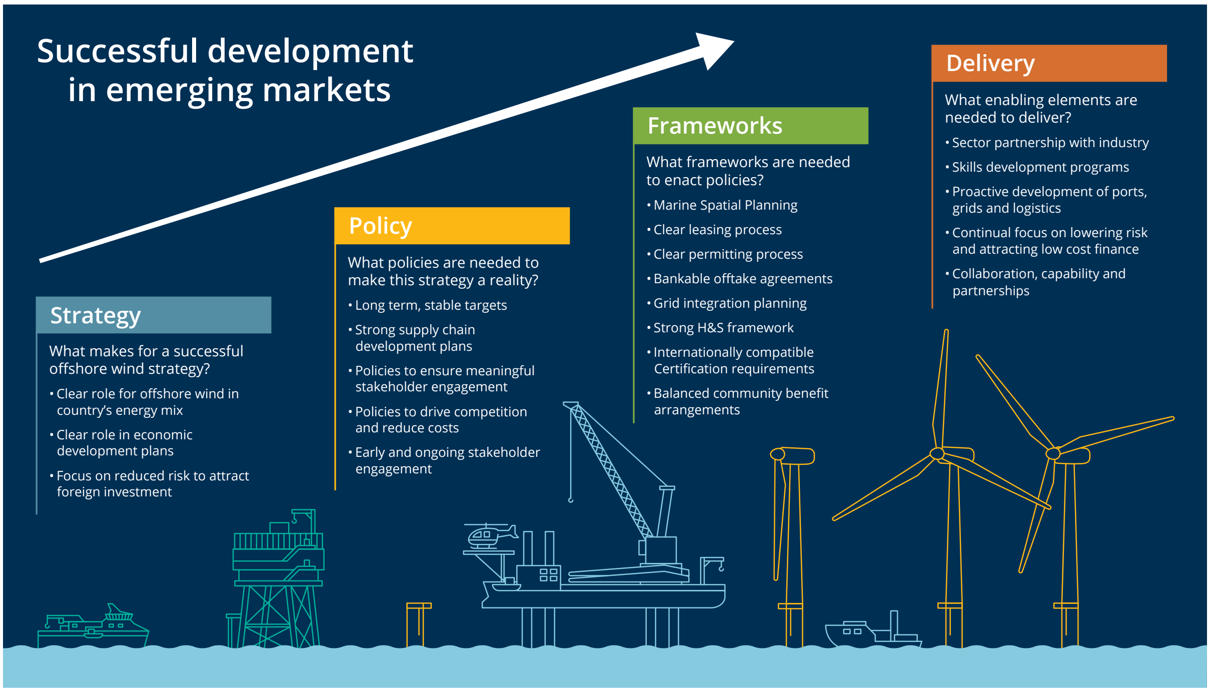
- Cost of energy, reflecting recent global trends.
- Marine spatial planning, reflecting emerging best practice.
- Offtake and revenue, reflecting the emergence of value factors as a component of auctions.
- Supply chain, reflecting latest global industry dynamics.
- Infrastructure development, including ports and transmission, reflecting its increasing prominence as a challenge to offshore wind development worldwide.

New sections have also been added relating to stakeholder engagement, community benefit, and collaboration, capability and partnerships. Revisions include relevant experience from several new markets and lessons learned from the World Bank Group's roll out of roadmaps for offshore wind in Azerbaijan, Brazil, Colombia, the Philippines, Romania, Sri Lanka, Türkiye and Viet Nam and extensive technical assistance and capacity building in those markets.

INTRODUCTION

Photo credit: Vestas

FIGURE IN.1.1: STRATEGY, POLICY, FRAMEWORKS 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 illustrated in Figure IN.1.1. Each pillar includes multiple elements and key success factors. These pillars are linked, and together progressively refine the feasibility, viability and deliverability of offshore wind in a market. 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 is much less likely to 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

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

- Technical and economic feasibility of offshore wind and the potential fit of this technology in the country's energy system.
- Country-specific strategic objectives in the pursuit of offshore wind, which can include energy security, energy transition, addressing climate and environmental objectives, industrialization and employment externalities, export, investment stimulations and more.

Chapter 2 Policy

Presents relevant policy levers to translate strategy into reality. This will give market confidence and inform government priorities for the creation of frameworks and delivery support initiatives. These policies aim to define the priorities and settle the trade-offs between potentially conflicting elements of the strategy. 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.
- **Stakeholder Engagement.** Dialogue with the public, relevant bodies and industry to provide forward visibility of plans, gather feedback and build consensus.

Chapter 3 Frameworks[1]

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

- **Organizing frameworks**. Ensuring coordination for an efficient and cost-effective project implementation.
- **Marine spatial planning.** Enabling larger volumes of offshore wind to be sited in the most environmentally, socially, and commercially appropriate locations.
- **Seabed access rights.** Providing project developers exclusive rights to survey the sites on which to then construct and operate offshore wind projects.
- **Permitting.** Providing project developers permission to construct and operate offshore wind projects that are deemed to be acceptable.
- **Revenue and offtake.** Ensuring revenue streams are attractive enough to enable investment decisions in offshore wind projects, typically through long-term bankable offtake arrangements.
- **Export system and grid connection.** Ensure transmission networks can accommodate offshore wind.
- **Health and safety**. Minimizing workplace risks and protecting onshore and offshore workers

1 For definitions of terms in this section, see Appendix C.

- **Standards and certification.** Managing risk through standardization and certification to international standards.
- **Community benefit.** Ensuring communities located close to offshore wind farms and associated onshore transmission assets to receive proportionate economic benefit

Chapter 4 Delivery

Describes the foundational blocks of the delivery of offshore wind projects:

- **Supply chain.** 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.** 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. This includes managing risks relating to environmental and social considerations, as well as economic risks in alignment with international lender expectations.
- **Collaboration, capability and partnerships.** Harnessing and building expertise within government, industry, and international bodies to drive forward and derisk delivery.

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 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.

Appendix B: References provides a full list of reference sources.

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

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 answer to this question is not obvious and will vary from one country to another, depending on the country's priorities and the feasibility and viability of offshore wind in that country. Like any technology, offshore wind will be more or less difficult to implement and attractive to government and industry depending on the country context. It is essential for governments to define why they would pursue offshore wind, what are those strategic outcomes that offshore wind can help achieve and what are the trade-offs relating to the roll out of offshore wind.

The first step in answering this question is to **understand the economic feasibility of offshore wind** in the waters over which the country has internationally recognized rights. This assessment considers the wind resources, water depth, distances from infrastructure and other offshore characteristics in locations where biodiversity and social sensitivities are sufficiently low, but also needs to consider the economics of alternative low-carbon generation technologies, and the role offshore wind could play in a cost-effective decarbonized energy system.

Fixed offshore wind[2] is a mature technology, with a proven track record in many markets. The timelines of technology development are important in order to ensure that the realization of projects and technology risk can be reasonably managed.

Before embarking on a journey towards offshore wind deployment, it is important for governments 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 daily 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 local jobs, supply chain development and community benefit sharing?
- What contribution can it make to help meet climate and environmental objectives?
- How much foreign direct investment can it bring?

2 Fixed offshore wind is where foundations are firmly embedded in the seabed, as opposed to floating offshore wind, where foundations float and are moored to the seabed using anchors.

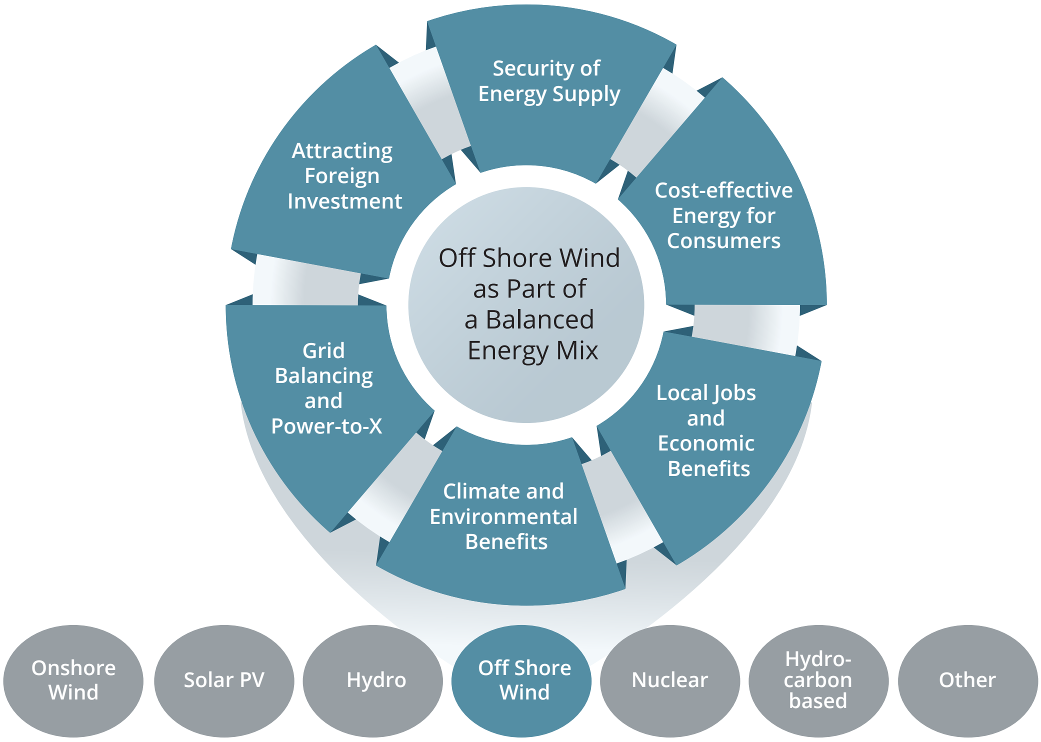
Any country interested in exploiting its offshore wind energy resources needs to answer the fundamental question *“should we develop offshore wind?”*

CHAPTER ONE:

STRATEGY

Photo credit: Maxwell Clarke

FIGURE 1.1: KEY CONSIDERATIONS FOR THE DEVELOPMENT OF AN OFFSHORE WIND STRATEGY



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)[3] alongside other forms of energy production, considering:

- Security of energy supply.
- Cost-effective energy for consumers.
- Local jobs and economic benefits.
- Climate and environmental benefits.
- Grid balancing, energy storage, and conversion.
- Attracting foreign investment.

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

Security of energy supply

Offshore wind can help meet increasing electricity demand in emerging economies and reduce reliance on imported fuels. Imported fuels used for electricity generation can be subject to significant price fluctuations. Offshore wind costs are mainly fixed before construction and can help a country achieve the security of its energy supply and energy independence.[4] Examples of energy strategies incorporating offshore wind can be seen in the UK (Case Study *2.3*) [1] and in Denmark [2].

Offshore wind projects provide large-scale electricity generation, with higher capacity factors[5] than onshore wind and solar projects. Projects exceeding 1 GW, with capacity factors of greater than 50 percent, are in operation or development in numerous markets. Offshore wind power plants typically benefit from more consistent and higher wind speeds[6] than onshore wind [3]. This can result in lower variability output on an hourly or daily basis, which is beneficial for system balancing. For this reason, the International Energy Agency (IEA) has categorized offshore wind as "variable baseload" generation (see section 4.4).

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[7] technologies.
- Utilizing 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.

Cost-effective energy for consumers

Site conditions, especially mean wind speed and water depth, play a key role in determining the viability of offshore wind projects. It is important to focus on developing sites with the most favorable conditions, whilst fully considering environmental and social sensitivities, to minimize the cost to consumers, and to recognize that the cost of offshore wind will not compare favorably with other forms of renewable generation in all locations. See section 2.3 for further details on cost of energy, including discussion of fluctuations in the early 2020s.

In emerging markets, the costs of early offshore wind projects may be higher than other energy sources, but over time, 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 does not necessarily exclude offshore wind from an energy strategy due to the potential long-term benefits to the system, the economy, the climate and other strategic objectives a country may have. In established markets, auctions are showing that new offshore

4 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.

5 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.

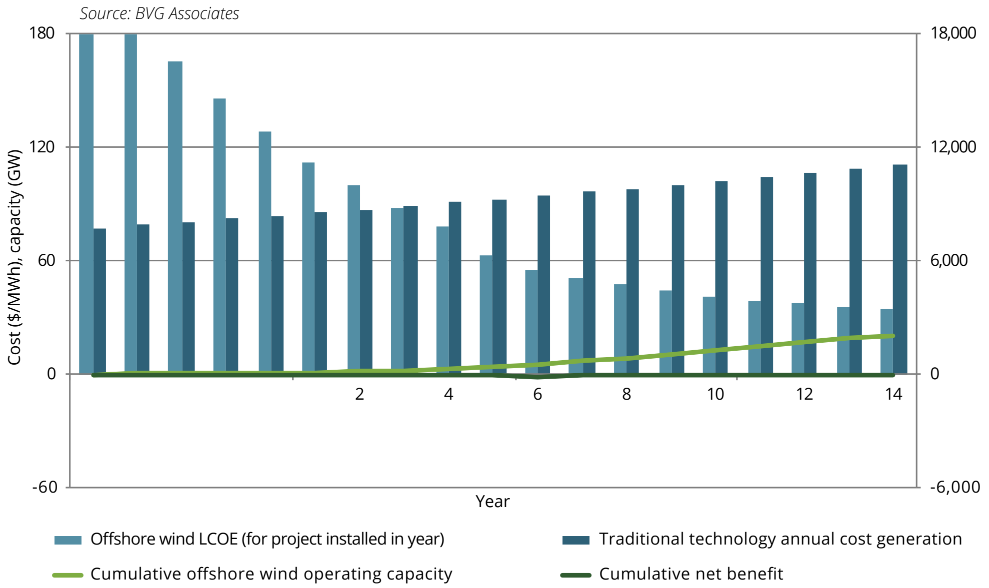
6 Offshore winds are generally more consistent in terms of wind speed and direction than onshore.

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

wind is already delivering lower levelized cost of energy (LCOE) than new-build nuclear and fossil fuel plants [4] [5]. The same trend will be available for emerging markets of sufficient scale and wind resource.

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 1.2 uses data from the World Bank Roadmap for Offshore Wind in Vietnam [6]. It shows the trend that in early years there is a net cost for production from offshore wind, but that lower cost production from offshore wind leads past a break-even position to a three times larger cumulative benefit 15 years from the start of the industry, 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.

FIGURE 1.2: LCOE AND CUMULATIVE NET BENEFIT OF OFFSHORE WIND IN A HIGH-VOLUME EMERGING MARKET



Source: Adapted from [6].

Markets that have clear policies and robust frameworks to nurture an offshore wind industry can significantly reduce the cost of energy over time. 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 [5], bringing offshore wind costs below wholesale market prices. Cost reduction is not guaranteed however, and recent increases in commodity prices and cost of capital have seen European LCOEs increase. Moving forward, offshore wind is expected to resume a long term trend of cost reduction as the industry grows and more markets establish.

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 useful 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.

The blue 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. The gray 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.

Coupled with expected future rises in conventional fossil fuel generation costs, this will make offshore wind more cost competitive against other technologies and increase its strategic relevance for more countries. Local characteristics such as wind resource and water depth will continue to influence how cost-competitive offshore wind can be. At the same time, relative costs of other key technologies such as onshore wind, solar, hydropower, geothermal and energy storage will influence the most economic solutions to transition to a net zero carbon energy system. It is important to assess the potential contribution of each to help establish a cost-effective strategy. This can best be done through an integrated spatial merit-ordered based study considering resource availability, transmission network upgrades and system balancing.

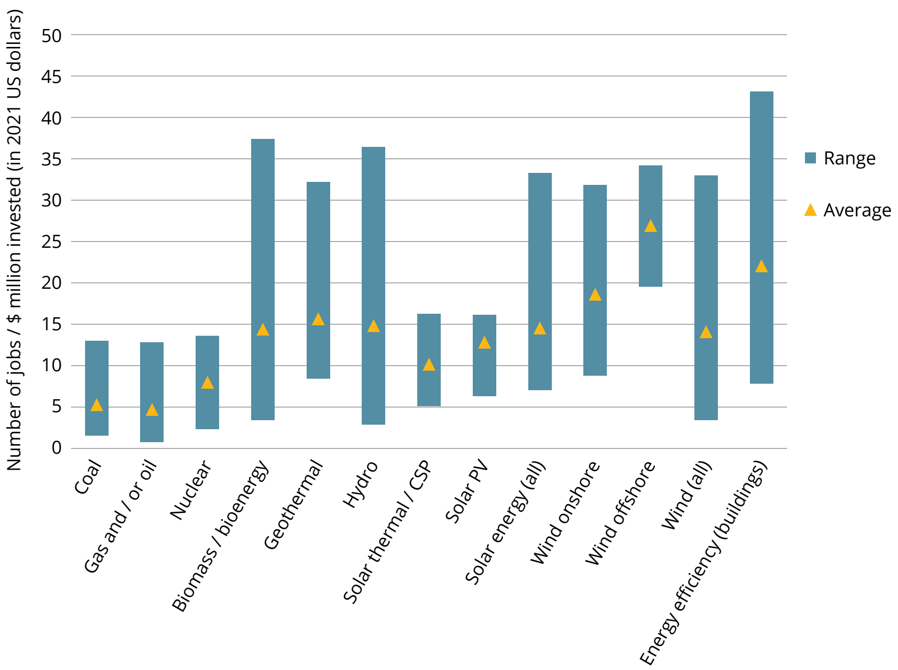
The early 2020s saw a period of turbulence affecting all energy markets and technologies in various ways. In the case of offshore wind, commodity and labor cost, financing cost and supply chain pressures in the face of fast but uneven market growth have impacted project costs. Other generation technologies have also been under cost pressure but have recovered from the turbulence more quickly as their supply chains are less complex.

Floating offshore wind in deeper water is likely to be rolled out at progressively larger scale as technologies mature, helping the supply chain adapt to its requirements and strengthen its commercial viability. The offshore wind market currently is dominated by fixed foundation projects (up to about 70 m water depth), but over the next 20 years this is likely to change, opening up new markets with good wind resources close to population centers, but with deeper water. It is important for governments to consider the floating offshore wind opportunities as they develop their marine spatial planning and evolve their energy strategies. Turbines for floating projects are almost the same as for fixed, but foundations, installation methods, and port requirements (see section 4.3) are quite different.

Local jobs and economic benefits

Offshore wind has the potential to generate more economic benefit than most other forms of electricity generation by creating local jobs to support the development, manufacture, construction, and operation of projects. Taking an average of studies completed, each with a somewhat different basis, shows that offshore wind creates about 25 jobs per US$ million invested, more than double solar PV and five times more than fossil fuels, as shown in Figure 1.3 [7].

FIGURE 1.3: COMPARISON OF GROSS JOB CREATION BY DIFFERENT ENERGY TECHNOLOGIES BY LEVEL OF INVESTMENT



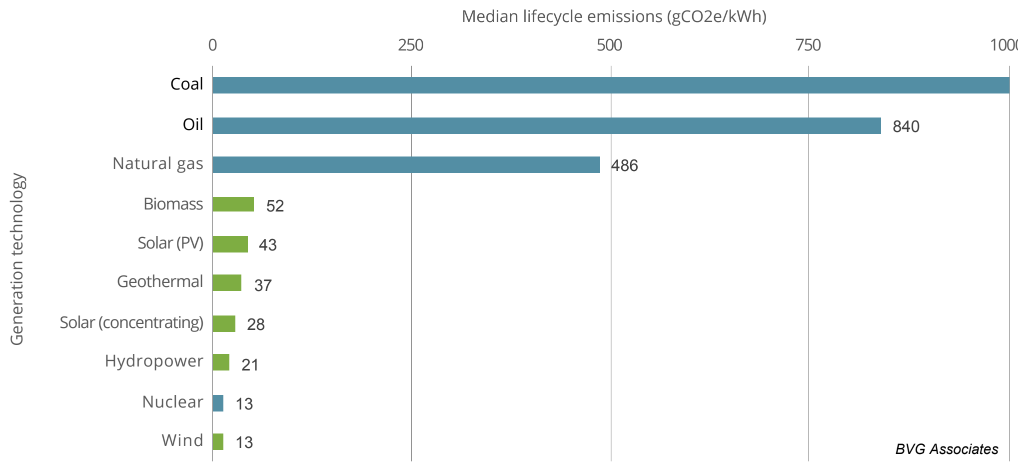
Source: Hanna et al. [7]

The level of localization of supply chains depends on domestic capability and capacity, and the strength of the investment case for global and regional suppliers. Not all countries will be able to attract material parts of supply chains, however ports and operations and maintenance facilities drive long-term economic activity during the whole life of a project. 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 [5]. It is, therefore, important for governments to consider offshore wind not only in an energy context but look at broader aspects such as labor market and inward investment conditions. See section 2.4 for a more detailed discussion of employment, including the types of jobs created during the development, construction, and operating phases of offshore wind projects.

Climate and environmental benefits

Due to its scale, 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 [5], whereas the lifetime emissions from offshore wind are equivalent to between 5 and 13 metric tons of CO_2 per GWh [8]. As indicated in Figure 1.4, offshore wind is one of the most effective forms of variable renewable generation to displace coal from the perspective of emissions avoidance [9]. This helps countries meet their nationally determined contributions as part of the UN Paris Agreement [20].

FIGURE 1.4: MEDIAN LIFECYCLE EMISSIONS OF DIFFERENT ENERGY GENERATION SOURCES.



Source data: NREL [10] [8]

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 [5]. In addition, thermal generation requires, on average, 15 million liters of water per GWh [5] 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 0).

There are already bans on new coal power stations in a range of countries, and more of these are likely to be put in place over the coming years [11]. Countries such as the Philippines [12] and utility companies across the European Union have halted construction of new coal power stations [13]. The UK and Portugal have already phased out use of coal fired generation (see Case Study 1.1), while other countries such as Denmark and Italy [14] have fixed dates by when no coal generation will be permitted. Certain financial institutions have also implemented policies restricting financing for coal power projects. DNV anticipates about 85 percent of global electricity will come from renewable sources by 2050 [15].

8 Renewable technologies are represented in green, and non-renewables in blue. Wind emissions figures are a combined median of estimates for onshore and offshore technologies (generally quite similar). Photovoltaic emissions are based on thin film and crystalline silicone technologies. Concentrating solar power emissions are based on a tower and trough design, and nuclear emissions on a light-water reactor. Emissions for hydropower represent a combined median of estimates for run-of-river and reservoir hydropower technologies. Biogenic emissions are not included.

CASE STUDY 1.1

The UK's transition away from coal generation

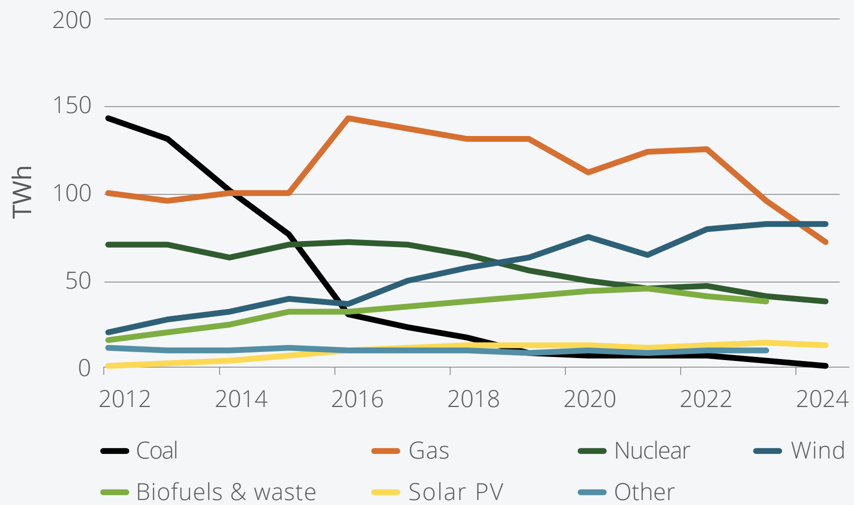
In the early 2010s, coal fired generation made up the largest proportion of the UK's electricity generation mix. With the introduction of the Carbon Price Floor, which set a minimum price that power stations had to pay per metric ton of CO_2 emitted, the competitiveness of coal versus other less carbon intensive generation sources was diminished, leading to a rapid decline in coal generation over the coming years.

In November 2015, the UK Government committed to phasing out generation from unabated coal by 2025. This deadline was later brought forward to October 2024.

The UK recorded its first coal-free day in 2017, followed by weeks without coal in subsequent years as its share of the generation mix continued to fall, accelerated by the growing prominence of wind power within the UK energy mix.

The closure of the UK's final coal plant, at Ratcliffe-on-Soar in September 2024 marked the completion of its journey away from coal power. The transition from coal to wind providing the largest share of electricity generation in the UK took 12 years, with coal dropping by almost 90 percent over six years, as shown in Figure 1.5.

FIGURE 1.5: TRANSITION FROM COAL TO WIND PROVIDING THE LARGEST SHARE OF ELECTRICITY GENERATION IN THE UK



Located in the right place and implemented well, offshore wind can provide nature positive solutions. Almost 200 countries have ratified the Kunming-Montreal Global Biodiversity Framework, with 2030 targets, including integration of biodiversity in decision-making at every level, and 2050 goals. See section 2.5, including Case Study 2.11, for more details.

Grid balancing, energy storage, and conversion

Offshore wind has a more stable, predictable generation profile compared to many other renewable generation technologies, meaning it can play a useful role in grid balancing in renewable-heavy electricity systems. Wind speeds are typically higher offshore, resulting in higher capacity factors and less generation volatility relative to onshore wind. In addition, offshore wind generation is typically less correlated with the day/night cycle, offering complementarity with solar PV- heavy systems. Grid balancing is a key strategic rationale for development of offshore wind in several markets, including Brazil and California — see Case Study 1.2.

CASE STUDY 1.2

The case for offshore wind as a system balancing technology in Brazil and California

Brazil

Brazil is currently heavily reliant on hydroelectricity for its electricity needs, making up 72 percent of the Brazilian generation mix in 2022. The World Bank Group's 2024 *Scenarios for offshore wind development in Brazil* report found that, that at the national scale, the seasonal variation in offshore wind power could complement the historical seasonal behavior of hydropower, offering value as in grid balancing. It also found that the proximity of planned offshore wind development zones to coastal population centers could yield benefits in terms of decreased infrastructure costs, transmission losses and grid instability [16].

Case Study 1.2 Continued

California, United States

The California Energy Commission (CEC] 2024 *Offshore Wind Energy Strategic Plan* recognizes the strategic value of offshore wind to play an important role in diversifying the state's generation portfolio. Solar PV makes up a large proportion of California's current energy mix, and offshore wind offers complementary generation source which is not correlated solar PV's significant day-night cycle. As in Brazil, the proximity of offshore wind development zones to major coastal demand centers offers additional benefit in terms of reduced transmission losses and infrastructure requirements [17].

Excess offshore wind generation may also have strategic value through conversion into low-carbon fuels such as green hydrogen and efuels. This is commonly referred to as Power-to-X (P2X). The P2X industry is currently in its infancy however, and the cost of these fuels remains high relative to fossil fuel alternatives. The WBG report, 'Scaling Hydrogen Finance for Development,' offers recommendations to encourage the development of hydrogen production in emerging markets, and to drive down costs [18]. Until there is further progress in this area, grid-connected offshore wind generation will remain a more economic and deliverable prospect for most markets.

Attracting foreign investment

The massive amounts of financing required for offshore wind projects mean that emerging markets will likely need foreign investment. Typically, wind farms of 500 MW to 1 GW-scale have multi-billion dollar investment needs. Often, local financing markets have insufficient liquidity to be able to finance multiple offshore wind projects alone. An important way for governments to facilitate inward investment and ensure competitive financing is to ensure their policies and frameworks encourage the development of bankable projects that meet international financing requirements.

Offshore wind has the potential to offer attractive investment opportunities [19]. With the correct frameworks in place to manage risks, large pools of capital can be available. 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 [20].

International financing for offshore wind requires environmentally and socially sustainable development, in-line with Good International Industry Practice (GIIP) [9], global goals for biodiversity conservation and carbon emissions reduction. Robust frameworks have been developed and refined over the years to improve the sustainability of investments. The World Bank has been a long time leader in these efforts through its Environmental and Social Framework implemented in its operations [21]. With respect to the private sector, the International Finance Corporation has developed its Performance Standards which set the benchmarks for E&S assessment and management to ensure the bankability of projects [22].

9 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 [388].

Both 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 in emerging market countries.

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) [23], can attract low carbon investment in ways that investment in generation from fossil fuels cannot.

Concessional finance can help facilitate investments in offshore wind by mitigating certain project risks or bridging a gap in project viability faced by investors. The WBG has published an extensive report on the potential impact of concessional financing on accelerating the implementation of offshore wind [24]. Concessional financing can be an efficient tool for reducing the costs of the first projects. However, with the scale of offshore wind projects, the scale of concessional finance required is similarly large. WBG projects that $15.6 billion of concessional finance (as both debt and grants) would be required to facilitate 10 GW of projects.

The market for international investment is competitive. As more countries deploy offshore wind, project developers are carefully choosing markets in which they invest human and financial resources to advance projects. In the early 2020s, a series of developers pulled out of markets they deemed to be less attractive for investment than others. In this context, it is important for governments in emerging markets to ensure the environment for investment is as attractive as possible. It is advisable to conduct engagement with developers prior to any auction event to ensure there is sufficient interest to generate viable competition. Key considerations for developers when prioritizing markets for investment include:

- Strength of strategic case for offshore wind, considering factors such as wind resource, transmission network and electricity demand.
- Transparency and predictability of frameworks for offshore wind.
- Levels of government support available.
- Scale and visibility of long term pipeline.
- Environmental and social factors.
- Political stability and wider commercial / legal arrangements.

A strategic approach to tender design needs to ensure clarity of the investment case, without diluting strategic priorities with additional requirements. For example, if delivering cost-effective energy for consumers is the key priority, governments should promote ease of delivery and avoid complications that would drive up costs or uncertainty. Offshore wind strategies which seek to deliver conflicting policy objectives may result in overly complex delivery frameworks, disincentivize investment and dilute ability to meet core objectives.

Key success factors

Strategic assessment of offshore wind by a country should:

A. **Identify the resource potential of offshore wind.**
Based on marine spatial planning and considering technical resources from windspeed and available sea area, limitations imposed by other sectors and environmental factors.

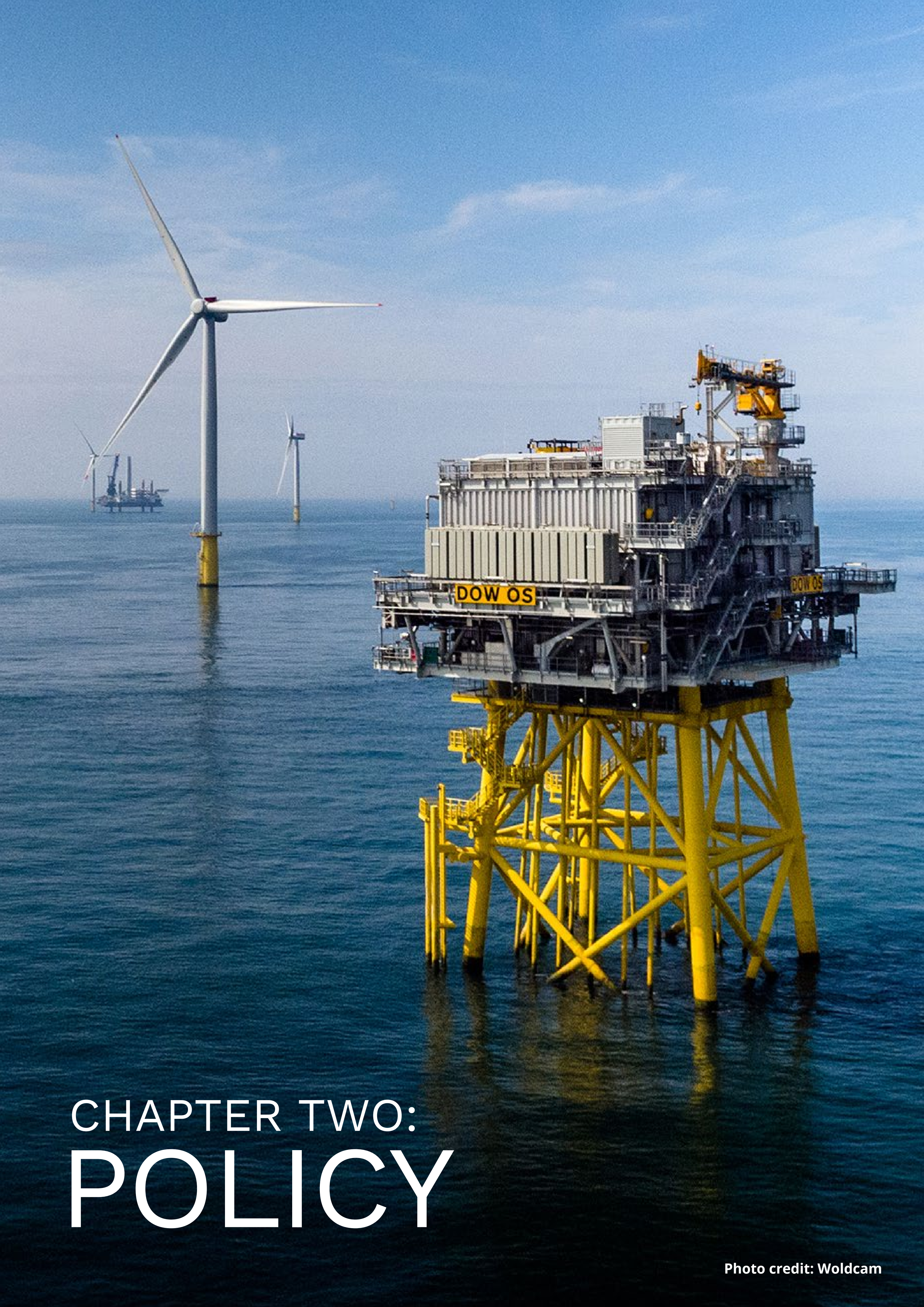
B. **Establish a clear role for offshore wind in the country's future energy mix.**
Taking into consideration electricity demand, energy system integration, long term objectives of reducing energy costs and CO2 emissions and promoting energy export potential.

C. **Identify industrial and societal objectives of offshore wind for the country.**
Including job creation potential, and integrate it into the country's climate, industrial, and economic strategies.

D. **Attract foreign development and investment partners.**
Based on robust regulatory frameworks including for revenue support and environmental and social safeguards.

E. **Open the dialogue with market participants and wider stakeholders.**
Create transparent processes for review and revision of policies, whilst maintaining stable frameworks.

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



CHAPTER TWO: POLICY

Photo credit: Woldcam

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 does offshore wind fit in the country's energy mix and how much offshore wind capacity do we want by when?
- 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?
- How should the government engage with stakeholders to provide forward visibility of plans, gather feedback and build consensus?

Figure 2.1 summarizes these key policy levers to be employed in implementing an offshore wind strategy.

FIGURE 2.1 KEY POLICY LEVERS TO IMPLEMENT AN OFFSHORE WIND STRATEGY

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.

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.

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.

2.5 Environmental and Social Sustainability

Offshore wind projects have implications for ecosystems and regional communities.

2.3 Cost of Energy

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

2.6 Stakeholder Engagement

Governments undertake stakeholder engagement as part of the implementation of frameworks and delivery support initiatives.

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 are best delivered at large scale and the development of such infrastructure projects and associated supply chains can take years to establish — far longer than a typical political cycle.

Aspirations, plans, and reasons to facilitate offshore wind deployment need to be clearly stated by governments to enable industry investment. 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. The more consensus there is for offshore wind across major political parties, the more confidence the industry will have in that market as the perceived political risk is reduced.

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 which elements are of greatest importance. Examples of clearly stated policy targets include the Netherlands' *National Climate Agreement* [25], New York's *New York State Offshore Wind Master Plan* [26] [27], Poland's *Offshore Wind Act* [28] and Japan's *Offshore Wind Industry Vision* [29]. These policy targets were then adopted into legislation, which reduces the risk of targets being removed by a future government.

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 2.2, adapted from the *Japan Cost Reduction Study* [30]. A common approach to creating local jobs and economic benefit is to require local content[10] as part of development rights (light blue in Figure 2.2). However, experience in markets such as France and Taiwan, China, has shown that prescriptive or stringent 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.

Policy implementation is most effective when supported by a clear overarching strategic plan bringing together deployment ambitions with marine spatial planning, grid development and other relevant national priorities. See Case Study 2.1 for examples of strategic plans.

10 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 [255]. 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

Strategic offshore wind plans in the UK and Viet Nam

UK

In the UK, the Government's strategic vision for offshore wind is underpinned by *Clean Power 2030.*

Action Plan: A new era of clean electricity, published in December 2024. [31] The plan establishes the UK's 2030 deployment ambitions across a range of technologies, including plans for 43-50 GW of offshore wind, 27-29 GW of onshore wind and 45-47 GW of solar, and for battery storage. It sets out plans for grid connection and consenting process reform, electricity market reform and supply chain and workforce development to facilitate these goals. [31]

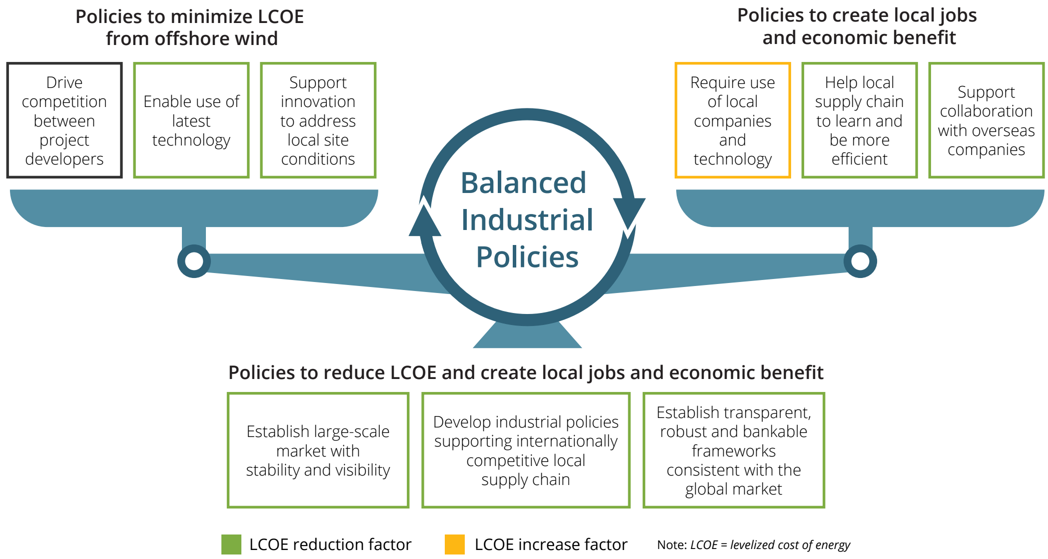
Viet Nam

Viet Nam's strategic offshore wind plan is set in Government's *Power Development Plan VIII* (PDP VIII), approved in May 2023.

PDP VIII set a target to install at least 6 GW of offshore wind by 2035 and between 114 and 139 GW by 2050. It also includes consideration of necessary transmission grid developments, including interconnection, to enable these deployment ambitions.

In both cases, consideration of an integrated, system wide strategy and clear levels of ambition strengthens the strategic rationale for offshore wind deployment, and bolsters investor confidence in the deliverability of stated renewables deployment ambitions.

FIGURE 2.2: POLICY BALANCE BETWEEN COST OF ENERGY AND LOCAL ECONOMIC BENEFIT IN THE EARLY STAGES OF EMERGING MARKETS



Note: LCOE = levelized cost of energy

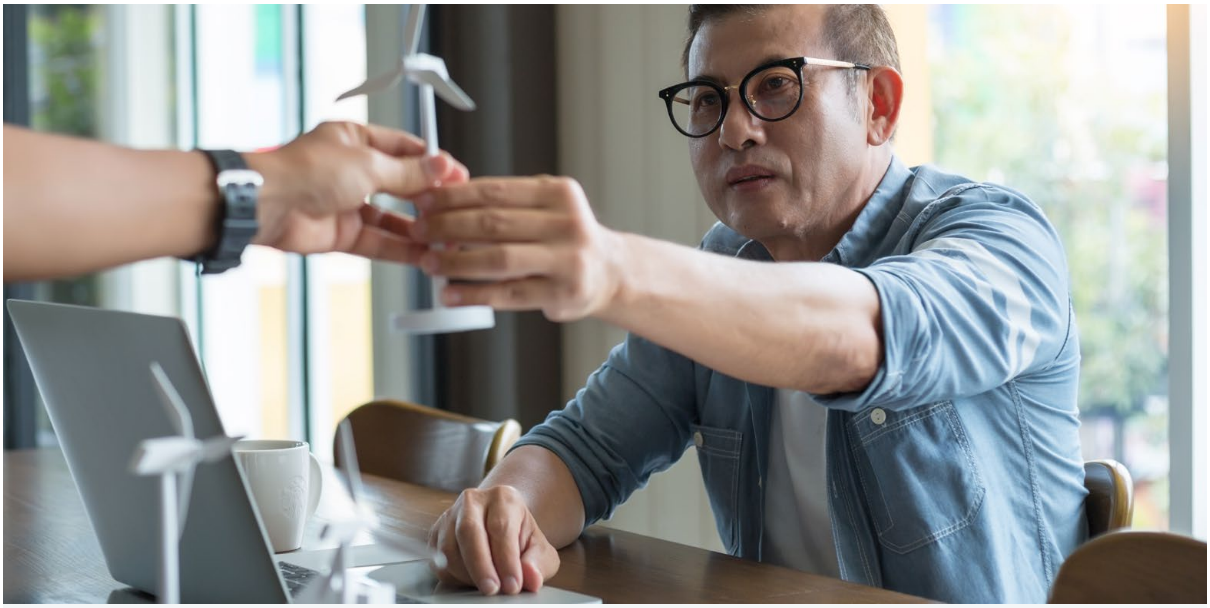
Collaboration with industry is key to successfully building and evolving policy. A government's policy objectives and priorities can change over time. Industry needs to understand the government's reasoning and to be given the chance to provide feedback on government plans to ensure that objectives are reasonable and can be met. Case Study 2.2 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.

CASE STUDY 2.2

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) [32] [33].
- Ensuring that policies prioritized cost competition over creating local jobs and economic benefit.



Case Study 2.2 Continued

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 [34]. 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 long term capacity targets, coupled with certainty of regular offtake auctions and targets focused on economic benefit. It has worked with industry to put in place processes to deliver, including:

- Offshore Wind Growth Partnership [35], 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) [36], 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 2.9.

Good examples of clear policy and legislation can be found in the UK and Poland. See Case Study 2.3. 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 2.3

Strong Offshore Wind Policy Drivers and Legislation—UK and Poland

UK energy white paper: Powering Our Net Zero Future [37]

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 £50 million (US$63 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 [38].

Polish Offshore Wind Act [39]

Poland's Offshore Wind Act came into force in February 2021. It set out the rules and regulations that would 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 was 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. Poland has subsequently increased its offshore wind targets, with a commitment to install 5.9 GW by 2030 and 18 GW by 2040.

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.

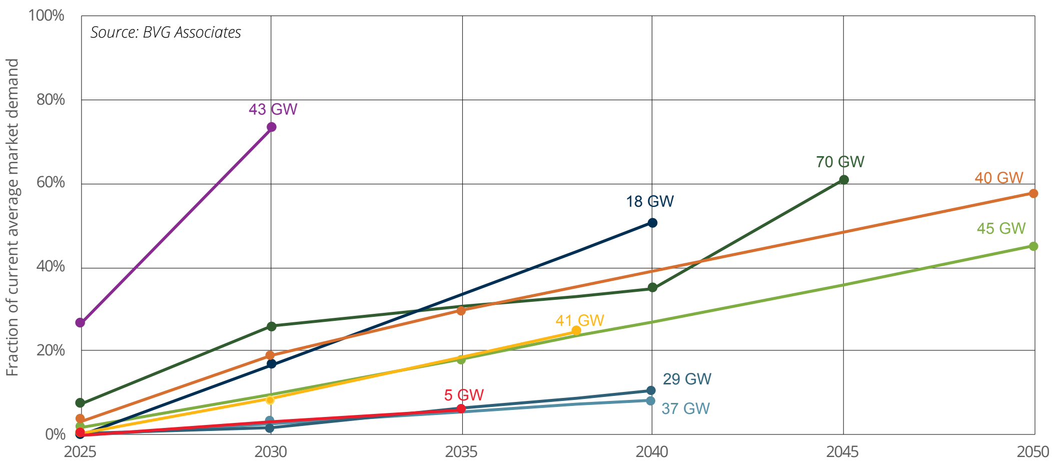
Volume

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 [40], Japan [29], and Poland [41]. These targets should be developed with industry engagement and can be conditional on the industry delivering LCOE reduction or local benefits.

The government must build confidence in its commitment to the large-scale deployment of offshore wind over the long term to attract industry and the large volumes of international financing needed. Examples of targets are summarized in Figure 2.3. It is recognized that market demand will change over the next 20 years based on population, demand reduction due to energy efficiency, and demand increases due to electrification of transport and heating.

Markets that have demonstrated long-term government commitment have built industry confidence. The UK, with its high short-term 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. In the same way, Japan has established and reiterated a target and continued to hold auctions to build the required pipeline of projects, whilst the US has shown inconsistency in its long term offshore wind ambitions which has seeded market skepticism.

FIGURE 2.3: EXAMPLES OF PUBLISHED NATIONAL OFFSHORE VOLUME WIND TARGETS, EXPRESSED AS FRACTION OF CURRENT MARKET DEMAND[11]



11 Japan and India have published targets for volumes auctioned [36]. These have been adjusted to anticipated volumes installed to match other markets, 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 2022 and 2023. The markers along each line show the years in which markets have committed to official targets.

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 [42]. Case Study 2.4 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.

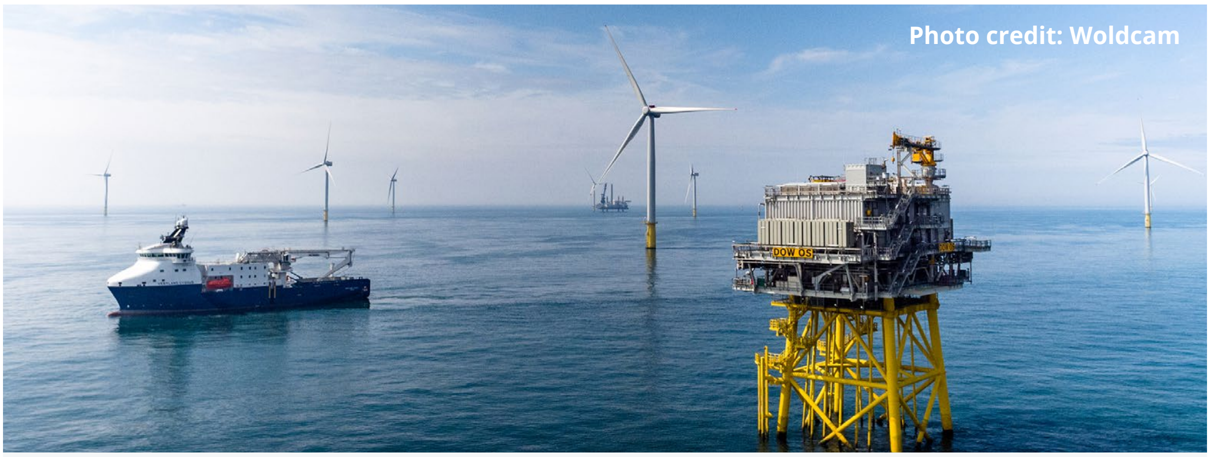


Photo credit: Woldcam

CASE STUDY 2.4

Long-Term Regional Visions for Offshore Wind

European vision

In 2019, WindEurope published *Our energy, our future* [43], 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 [44]. 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.

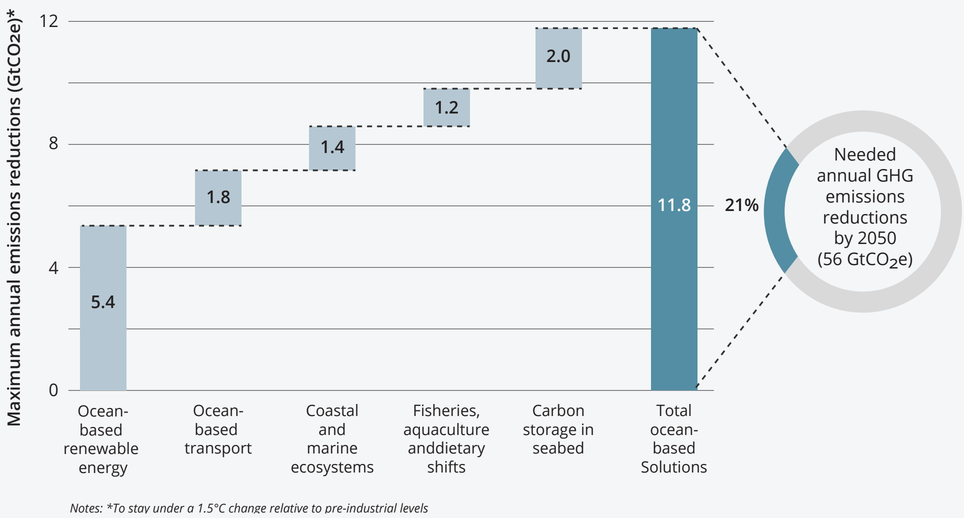
Case Study 2.4 Continued

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 [5]. 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 2.4, 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 2.4: CONTRIBUTION OF FIVE OCEAN-BASED CLIMATE ACTION AREAS TO MITIGATING CLIMATE CHANGE IN 2030 (MAXIMUM GTCO2E) [45]



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 2.5). 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 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.

Demonstrating commitment to achieving those targets on a clear timeline is key to success. Investors and industry are aware that overcoming the trade-offs previously mentioned can be challenging and undermine progress towards the targets. Consistency in progress from policy setting to framework design and implementation and clarity in timeline are building blocks of trust with market participants.

CASE STUDY 2.5

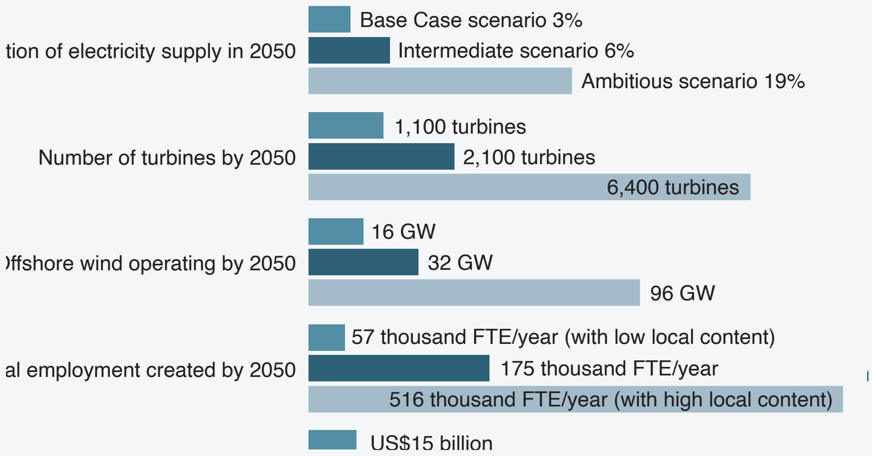
Brazil: The Positive Impact of Volume on Local Economic Benefit

As shown in Figure 2.5 , the World Bank Group's Scenarios for offshore wind development in Brazil [16] estimates that a sixfold increase to volume capacity targets over a 26-year period could increase the local jobs created by 9 times during the period, and local GVA creation by 11 times, in the Ambitious scenario, compared to the Base Case scenario.

In line with the findings of this study, 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, and a greater level of ambition is likely to drive greater opportunities for supply chain localization.

Case Study 2.5 Continued

FIGURE 2.5: IMPACT OF OFFSHORE WIND IN BRAZIL UNDER BASE CASE, INTERMEDIATE AND AMBITIOUS SCENARIOS, 2024 TO 2050



FTE = full-time equivalent; TWh = terawatt-hour.
Source: [16]

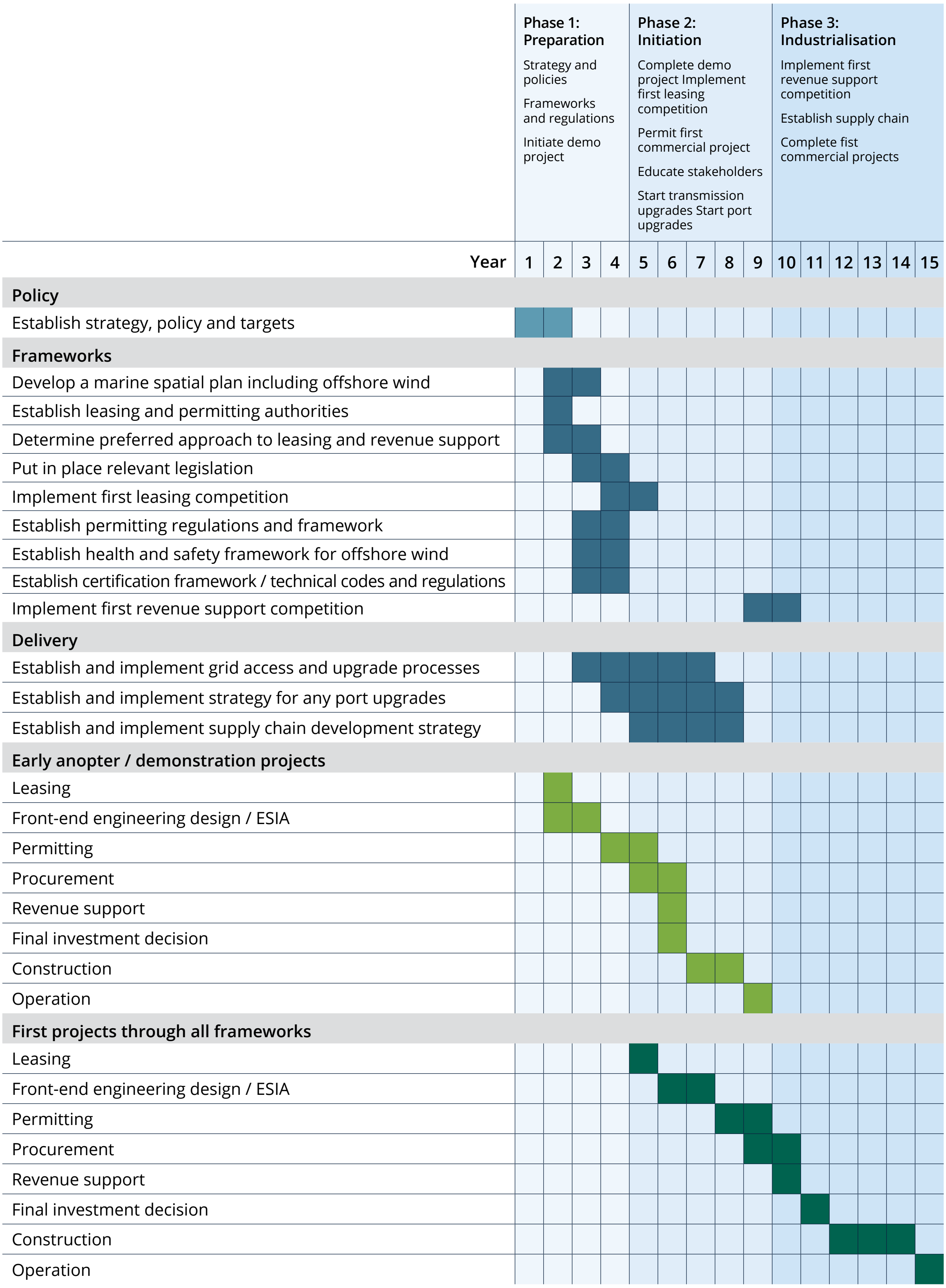
Timescales

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 must rapidly expand and then reduce their workforce. Suppliers that can supply to a range of export 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 supplied jackets to the Taiwan, China market, while the Korean market has been progressing slowly [46]. 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 2.6 for the case with separate seabed rights allocation 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 play a role in delivering long-lead items at at a national level, rather than leaving the responsibility to individual developers which can take more time. This could include commissioning early-stage regional-scale baseline studies to fill data gaps as explained in section 2.5. Marine Spatial Planning and seascape level baseline surveys can also help in this regard.

FIGURE 2.6: 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.

Offshore wind technology has significantly matured, in particular for fixed offshore wind. Although the industry sees constant technological innovation, there is much less need for new technology demonstration via small projects in multiple markets, or pilots. It is preferable, and easier from a supply chain perspective, to move directly to small (200-400 MW) or larger commercial scale projects, avoiding a delay to commercial deployment caused by work on demonstrators.

Governments should define clear outcomes for any pathfinder project. These may include:

- Proving that materially different physical conditions to established markets are suitable for the technology.
- Testing logistics where projects are being deployed in new locations, far from existing supply chain.
- Helping improve frameworks and build stakeholder capacity in readiness for a pipeline of larger projects.
- Triggering development of infrastructure (e.g., port upgrades for construction and operation, transmission reinforcements) that can be used for multiple future projects.

Floating offshore wind in deeper water is likely to be installed in larger volume from the early 2030s. This technology will be vital for markets with good wind resources close to population centers, but with water depths over 70 m.

Pathfinder projects may be deployed by developers based on bilateral agreements or competitive processes. Several markets have first tested offshore wind deployment via small-scale demonstration projects. Examples include Japan [47], the Republic of Korea [48], Taiwan, China [49], and the US (see Case Study 2.6). Repeat technology demonstration in different markets are usually not needed as the industry has already gained significant experience. Overall demonstration projects can have high capital cost per MW installed, due to relatively high logistics costs and small contract sizes compared to commercial gigawatt-scale projects. As such, they can have the unintended effect of delaying the commercial roll-out of offshore wind in a country.

CASE STUDY 2.6

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, with a per MWh cost more than double later commercial scale projects [50], 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 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

Government policies on volume and timescales for offshore wind should:

A. Provide long-term stability and project pipeline visibility to help build industry confidence and ability to invest.

B. Target sufficient volumes of offshore wind to help drive down the cost of energy and grow local supply chain over time.

C. Set realistic time expectations to build an industry.

D. Consider using commercial-scale pathfinder 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 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. Figure 2.7 shows the typical range of LCOE[12] as a band. The LCOE is heavily dependent on:

- Site conditions, such as wind resource, export cable distance, and water depth.
- The scale of deployment opportunity and level of market experience.
- Intensity of competition and market appetite.
- Supply chain maturity and local content requirements, which are mostly recognized to increase LCOE — however in certain markets where industry appetite was strong, accelerated localization of the supply chain has helped benefit from lower manufacturing costs.
- The cost of commodities (especially steel, copper, energy, labor and capital).

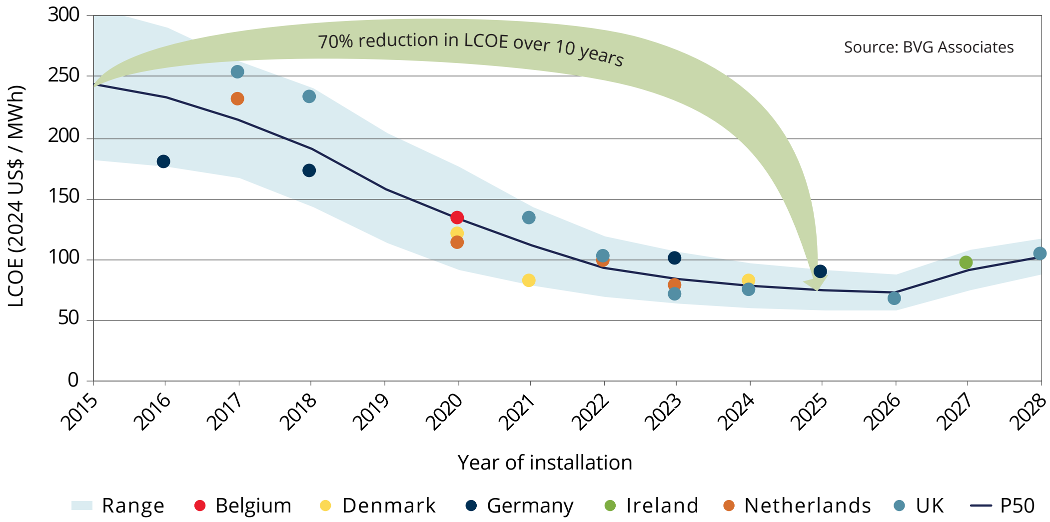
12 LCOE relates to the cost of generation and covers wind farm and export system, but not transmission network upgrades beyond the grid connection point. This differs from the revenue per MWh earned by the developer and the electricity cost to the consumer, which also includes balancing, transmission, and distribution costs.

The blue band covers 90 percent of estimated project LCOEs in established markets, incorporating offshore grid connections.[13] Individual projects are shown, where such calculation has been possible. The P50 line[14] indicates average LCOE. In France and Taiwan, China (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.

Although offshore wind experienced a decade of continued and significant cost reduction, several shocks in early 2020s have led to a market adjustment of the cost of offshore wind. In the period 2020 to 2025, there has been an increase in LCOE of about 20 percent. The main driver has been increased steel and copper prices (that have already started returning towards previous levels), increased cost of capital, increased labor costs and increased transport costs. Although many sectors of the economy and most energy technologies were initially similarly affected, offshore wind has experienced a more sustained re-assessment of its cost base than Solar PV or battery storage for instance.

Today, floating projects (not shown in Figure 2.7) have a higher LCOE than fixed projects, but over time they may become cost competitive on a like-for-like basis as more floating wind capacity is deployed, and risks reduce as the floating technology and supply chain mature.

FIGURE 2.7: COST OF ENERGY REDUCTION TRAJECTORY IN ESTABLISHED MARKET



Source: [51], [52]

Despite the market adjustment of the period 2022-25, the overall reduction in the cost of energy remains significant since the inception of the industry and is due mainly to the use of larger turbines, larger scale projects, increased competition, and reduced project risk. The ongoing trend toward use of larger turbines is a race to lower the cost of energy, enabling higher energy yield and lower $/MW cost for foundation, manufacturing, installation, and operation. Many studies are available that explore the key technologies and market drivers for cost reduction [30] [32] [53] [54] [55] [56] [57] [58] [59]. A key driver has been competition at the

13 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 2024 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.

14 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).

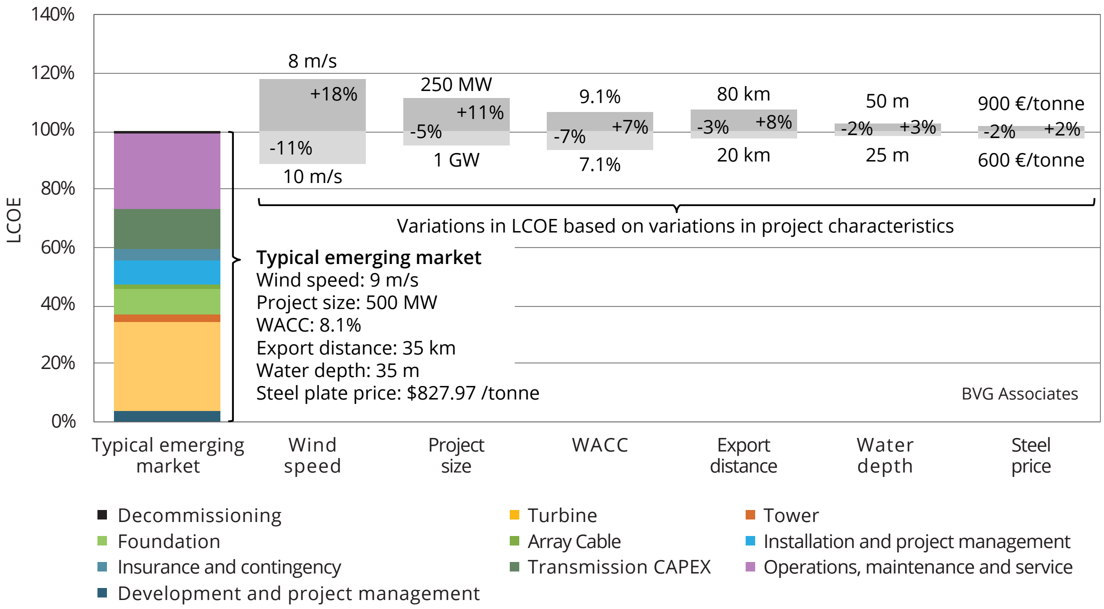
highest level within the supply chain, often driven by competitive auctions. Reduced project risk due to experienced suppliers learning to work well together also reduces the cost of financing, which has a significant impact on the cost of energy.

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

- Favorable wind resource.
- Large-scale projects as part of a large long-term project pipeline.
- Use of large turbines in large projects.
- Minimizing cost of finance (WACC)[15] through effective frameworks and well managed project risks relating to seabed rights and permitting ,as well as environmental and social impact risks in line with international lender expectations, through to stable operating revenue from a robust offtake agreement.
- Projects closer to shore and with shorter grid connections.
- Projects in shallower water.[16]

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 2.8.

FIGURE 2.8: TYPICAL LCOE BREAKDOWN OF A REPRESENTATIVE PROJECT IN AN EMERGING MARKET, INCLUDING IMPACT OF KEY PHYSICAL PARAMETERS



15 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.

16 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

Typically. early projects in a new market will have higher costs, but subsequent projects see cost reduction in the right policy and market conditions. Emerging markets are likely to see a similar pattern. Emerging markets will likely display the following features contributing to higher costs in first projects:

- 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 attributes not previously studied in the context of offshore wind), technical (for example, new ground or seismic conditions not yet experienced in offshore wind),social (for example inadequate consultation with coastal communities, including fishers) 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 2.7 for 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, including awarding rights on sufficient amount of seabed, 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, and managing environmental and social risks in line with international lender expectations.
- 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 2.7

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 [60].

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.

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

The Netherlands benefited from being a relatively small market with very favorable site conditions located in the middle of the booming North Sea basin regional market.

Setting realistic targets for cost of energy reduction, along with associated market volumes, helps industry to deliver. Targets can be aspirational, or actual ceilings in future auctions. Examples of governments setting longer-term LCOE targets include Japan [61] and the UK (see Case Study 2.8).

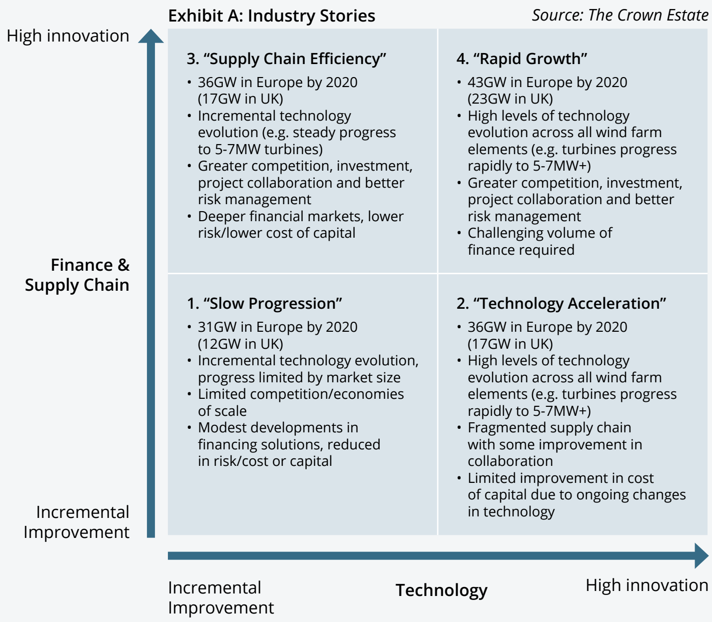
Commodity price changes after auctions impact viability of projects. Some governments have index-linked revenue support mechanism to protect developers from commodity price risk between revenue support award and project procurement. Examples of such mechanisms include Ireland's Offshore renewables support scheme [62], and New York State's Offshore wind solicitations [63].

CASE STUDY 2.8

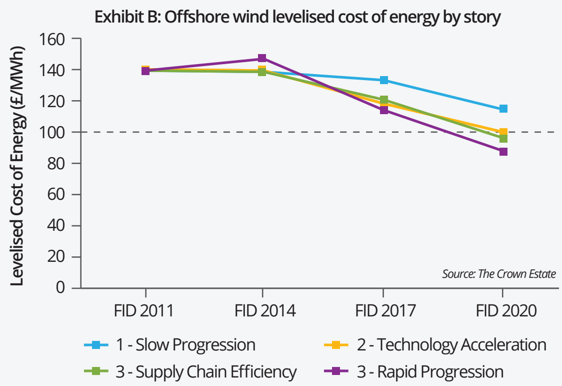
The Crown Estate Cost Reduction Study

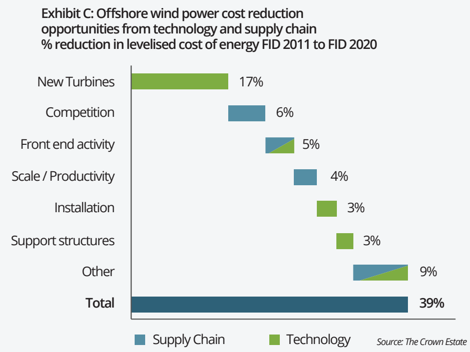
In 2012, the UK Government sent industry a challenge to reduce LCOE from around £150 (US$210) /MWh to £100 (US$140) / MWh over 10 years. Industry provided detailed technical evidence and set out a roadmap on how it would do this, with recommended actions that defined what it needed from the Government [32] [33]. Four scenarios, with UK deployment between 12 and 23 GW, were established. Three of these were projected to deliver LCOE meeting target, as show in Figure 2.9. The source of LCOE reductions in the Rapid Growth scenario is also shown.

FIGURE 2.9: KEY RESULTS FROM THE CROWN ESTATE COST REDUCTION STUDY



Case Study 2.8 Continued





Note: FID 2011 refers to a 500MW project whose Final Investment Decision is in 2011. Similarly for FID 2020. The period from FID to completing a wind farm is around three to four years. The cost reduction opportunities above are based on a comparison of a typical FID 2011 wind farm (3-5MW class turbine) vs. a typical FID 2020 wind farm (5-7MW class turbine).

For this comparison the cost of capital is held constant over time, and all costs are in 2011 money. Percentages are multiplicative not additive so the total is the product rather than the sum of the cost reduction elements.

Both the Government and industry built confidence in each other and agreed to the UK's first offshore wind sector deal [33], together enabling high volumes at low cost. With the backdrop of low cost of capital and significant global supply chain confidence, industry rose to the challenge and the LCOE target was achieved four years early, and with lower deployment than any of the four scenarios.

A fertile environment for cost reduction was established by, and in dialogue with industry:

- Setting long term volume expectations linked to LCOE reduction.
- A commitment to a regular and predictable series of offtake auctions.

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. Creating market scale by awarding rights on sufficient areas of seabed

C. Encourage a competitive environment through auctions and through investments in the local supply chain.

D. 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 job creation 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 offshore wind experience and competitive tension. Governments should consider local supply in the context of a competitive regional and global market. Apart from larger countries such as China and the US, individual national markets are generally 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 a pipeline of tens of GW over 5 to 10 years is required to create a competitive market for multiple suppliers. 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 domestic 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 2.9.

CASE STUDY 2.9

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.

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

Case Study 2.9 Continued

Taiwan, China

In Taiwan, the Government initially imposed strict local content requirements in specific areas of supply that developers must deliver or negotiate on. This drove the establishment of some local supply, but most recognize an associated cost penalty and risk of increased operational cost through use of less well proven solutions.

Since their introduction, Taiwan has successively softened these requirements. In 2021, the Government gave project developers increased freedom to decide how to deliver local content, but requiring project developers to source only up to 60 percent of these from Taiwan [64]. In 2024, following a World Trade Organization (WTO) dispute brought by the European Union, Taiwan committed to no longer include localization requirements in future allocation rounds, either as eligibility conditions or as award criteria [65].

UK

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) [34], leaving it to developers to decide the most advantageous way to incorporate local content.

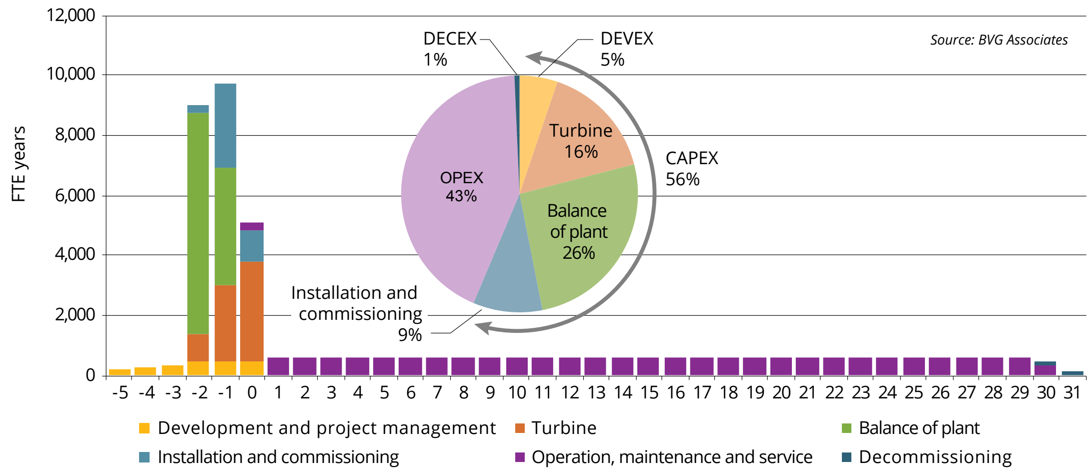
Best opportunities for local economic benefit

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 2.10 (adapted from *Roadmap for offshore wind in Vietnam* [6]). 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.

An installation rate of 1 GW of offshore wind per year typically uses about 25,000 FTEs per year in the capital phase (up until the start of operation). Each 1 GW of operating plant uses about 600 FTEs each year.[17]

17 In comparison, an International Renewable Energy Agency (IRENA) study in 2018 [342] 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.

FIGURE 2.10: JOBS FROM A SINGLE 1 GW OFFSHORE WIND PROJECT IN AN EMERGING MARKET



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

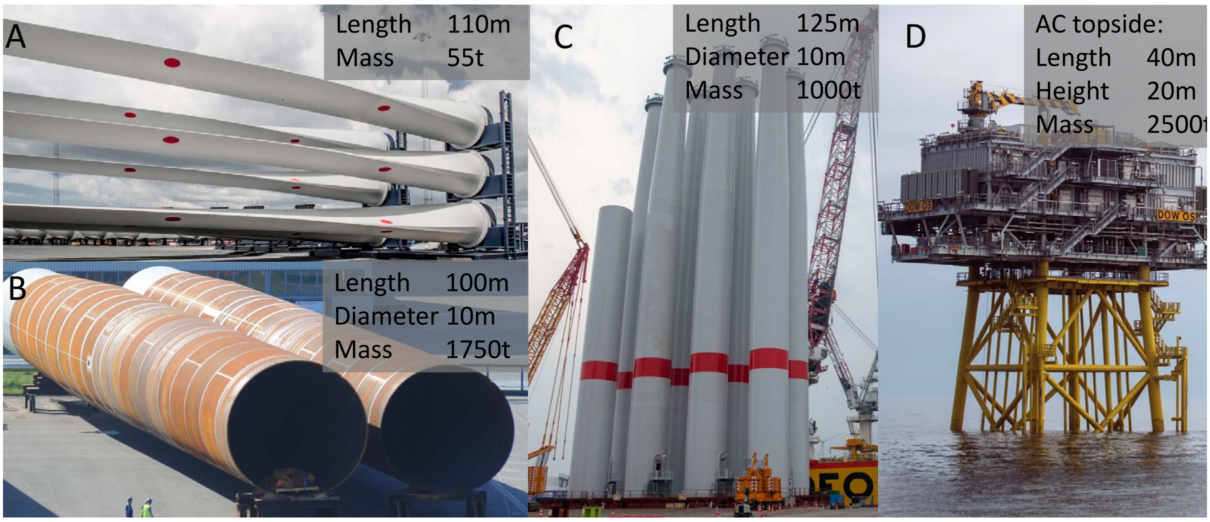
As an example, for a country installing 1 GW per year of offshore wind and with 5 GW of offshore wind operating, if it has 50 percent local content in the capital phase and 80 percent in the operating phase, it will be using about 15,000 FTEs per year. As the cost of energy reduces, the number of jobs also declines 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 of 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 2.11.

FIGURE 2.11: EXAMPLES OF LARGE ITEMS THAT ARE APPROPRIATE TO MANUFACTURE LOCALLY.



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.

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 CSBC and DEME to manufacture the first floating heavy lift and installation vessel in Taiwan, China.
- An experienced international supplier investing in a new facility, for example EEW (foundations) in New Jersey.

Industry purchasers (e.g. OEMs and Tier 1 component suppliers) generally prefer partnerships or an experienced supplier investing in a new market, 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 benefits of local supply.

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 practical and professional services [69] [70].

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 diversity, gender balance, and equality across their workforce [71]. An inclusive approach enables the best candidates to be chosen for the thousands of new jobs created by offshore wind; however, women frequently experience particularly high barriers to entry [72]. Policy makers, therefore, could 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 conditions 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 [34]. The Women in Wind Global Leadership Program, led by GWEC, provides best practices guidelines for gender diversity in talent recruitment [73].

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 have local and wider-scale implications for biodiversity,[18] ecosystem services,[19] and on socioeconomic attributes.[20]

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.

The integration of E&S aspects in offshore wind development is especially important given the nascent Kunming Montreal Global Biodiversity Framework (KMGBF [74]**).** This framework was ratified by 196 countries and adopted during the fifteenth meeting of the Conference on Biological Diversity Conference of the Parties (CBD COP-15) in December 2022. The KMGBF aims to halt and reverse biodiversity loss by 2030 and sets out an ambitious pathway to achieve the global vision of living in harmony with nature by 2050. This includes a target to ensure that at least 30 percent of marine and coastal areas are effectively conserved and managed through marine protected areas or other effective area-based conservation measures. The KMGBF is broadly recognized to set the agenda for achieving the 'Nature Positive' global goal[21] to 'halt and reverse nature loss by 2030 on a 2020 baseline and achieve full recovery by 2050'. A fundamental aspect of Nature Positive is that it also must be 'people positive', delivering long-terms benefits to people through healthy ecosystems and the services they provide.

In line with the KMGBF, it is important for governments to set priorities for marine spatial planning (MSP). This aligns with Target 1 of the KMGBF 'to plan and manage all areas to reduce biodiversity loss'. The MSP process enables governments to find routes to positive coexistence in the marine space and for stakeholders, including the wider public, to understand and engage on E&S and other concerns, and recognize the benefits of collaborative planning. MSP is therefore 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 [75]. Proportionate and focused spatial planning[22] of offshore wind projects, following MSP principles, can be used to inform leasing of offshore wind development. Moreover, there are potential synergies of undertaking MSP to integrate the identification of offshore wind development areas while also identifying new marine protected areas or other effective area-based conservation measures.

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

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

20 For example, other sea users and local communities.

21 Although this term is not specifically referenced in the agreement.

22 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. See also section 3.3.

Offshore wind E&S sensitivity mapping and MSP are useful precursors to fuller, multi-sector MSP and a worthwhile exercise when there is a need to accommodate accelerated timelines for offshore wind development. This may be the case in emerging markets seeking to rapidly deploy their first projects for any number of strategic reasons (e.g. energy security, climate goals etc.). Section 3.3 provides further discussion on both MSP and E&S sensitivity mapping. Significant impacts can often be avoided entirely if site selection is informed in this way. Avoidance at this early stage is most effective and will enable the identification of the lowest-cost mitigation measure available to governments and developers [76].

Governments can proactively commission early-stage, regional-scale characterization surveys to provide initial data and enable better scoping of project-specific environmental and social impact assessments (ESIAs). The baseline data gathered could inform spatial planning, sensitivity mapping, and site selection to reduce E&S risks to individual projects. Data collection can start early in a market's establishment (through MSP and sensitivity mapping exercises) before projects are awarded. 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. Case Study 2.10 highlights examples of government-led data collection campaigns to accelerate offshore wind deployment.

CASE STUDY 2.10

Government-led data collection campaigns to accelerate offshore wind deployment

In the US, the Bureau of Ocean Energy Management (BOEM), for example, frequently commissions baseline surveys and assessments for a wide range of biodiversity and social attributes, then publishes the findings to aid developers, stakeholders, and regulators [77].

In the UK, back in 2007, the Government commissioned *Aerial Surveys of Waterbirds in Strategic Windfarm Areas* which gathered data on the numbers and distribution of waterbirds and seabirds in UK inshore waters for use in permitting a range of offshore wind projects as well as identifying Special Protection Areas (SPAs). Prior to this, only limited data on the abundance or distribution of birds was available for many nearshore waters [78].

Case Study 2.10 Continued

In 2023, the POSEIDON project (Planning Offshore Wind Strategic Environmental Impact Decisions) was established to make a robust evidence base accessible through new mapping tools to support the expansion of low impact offshore wind development alongside thriving marine nature. The project is part of the Offshore Wind Evidence and Change Programme (OWEC) [38], led by The Crown Estate. It aims to create:

- A clearer understanding of the environmental risks and opportunities for future offshore wind developments (embedded into wider marine planning).
- Information to support developers, advisors and the ultimate decision-makers to plan, approve and build new offshore wind farms.
- A comprehensive environmental baseline platform that maximizes existing knowledge and allows future surveys and evidence collection to be more targeted.

The POSEIDON Benthic Storyboard provides a real-time summary of data collation and survey progress [79].

ESIAs are important for managing environmental and social impacts of offshore wind projects. They also identify appropriate risk mitigation measures and are typically a requirement of lender finance. 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.

Community benefit measures can also be important in ensuring the benefits of offshore wind deployment are equitably distributed. A focus on meaningful initiatives to address community concerns and priorities can help projects secure and maintain a social license to operate. See Section 3.10.

GIIP and lender requirements will help facilitate access to international finance and reduce delays. Following robust and well-informed early planning, a good ESIA will need to:

- Be conducted based on baseline surveys of the appropriate duration (see section 3.5).
- Ensure that a project is designed in accordance with the mitigation hierarchy (see Figure 3.6) 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. Use of nature based solutions may help achieve this.

- As more countries develop offshore wind, the risk of cumulative negative impacts [80] to sensitive habitats and species will increase. Many marine species are wide ranging and may be impacted in many countries through different stages of their life cycle or migration routes. Addressing these impacts and aggregating conservation action may be more successful if delivered through a national, or international process to provide strategic compensation, a last-resort method of offsetting impact in the mitigation hierarchy.

Governments should oversee a strategic approach to any compensation in relation to residual impacts on biodiversity. An ESIA may highlight residual impacts on biodiversity that have not been addressed through the application of the mitigation hierarchy. This is likely to be the case in relation to the cumulative impact of multiple projects within a region. In such circumstances, compensatory measures may be required to offset the negative impacts. Acknowledging that multiple projects will contribute to any cumulative impact, a collaborative approach to delivering compensation is likely to be required. The broad distribution of many of the species concerned, and the dispersed nature of many of the pressures acting on their populations, further make the case for a more strategic approach to compensation, rather than relying on developers implementing measures on a project-by-project basis. Examples of this approach have been set out by the UK Department for Energy Security and Net Zero [81] and the Scottish Government Offshore Wind and Marine Directorates [82].

Measures being taken to enhance biodiversity at offshore wind farms include a range of Nature-Inclusive Design modifications that aim to enhance, either directly or indirectly, biodiversity and ecological functioning, such as nature-friendly scour protection layers, cable protection layers, and add-ons such as those described in Case Study 2.11 [83] [84] .[23]

CASE STUDY 2.11

Nature-Inclusive Design examples for offshore wind

Offshore wind development in degraded marine ecosystems provides opportunities for biodiversity enhancement [85]. This can be actively encouraged through Nature-Inclusive Design (NID) measures associated with the infrastructure and protective features.

23 Note that Nature-inclusive design is a term that is sometimes used interchangeably with the broader Nature-based solutions, as defined by International Union for Conservation of Nature, IUCN [84].

Case Study 2.11 Continued

Whilst many enhancement measures are still being tested and developed, databases of effective actions are available, such as the OCEaN Energy & Nature Database [86] and The Rich North Sea Toolbox [87]. Many of these measures can be cost-effectively incorporated into existing requirements for offshore wind farms. Examples of cost-effective actions include:

- Water replenishment holes installed in monopiles. These enable an exchange of water inside the monopile to ensure the effective performance of cathodic protection measures inside the structure to prevent internal corrosion. These holes also enable marine species such as fish and crustaceans to shelter within the safety of the monopile. Designing an optimal number and size of these holes is an effective and low cost example of NID. These measures have been implemented with 30 cm x 1 m holes installed near the base of 140 turbines at the Hollandse Kust Zuid offshore wind farm in the Netherlands [88]. This measure is also being tested at Ecowende.
- Cable protection measures using mattresses made from bio-enhancing concrete. This incorporates a complex 3D texture, specially formulated to act as an artificial reef for benthic pioneer species like algae and sponges, which in turn attract crustaceans, mollusks, sea urchins and fish. These measures have been effectively applied on undersea power cables in the Canary Islands [89].

Using NID principles in scour protection stabilizes turbine and anchor foundations for offshore wind farms and protects the sea bed against erosion. These include the use of appropriate materials for marine life to establish as well as ensuring optimal spaces between tessellating structures to allow marine life to shelter. Appropriate substrates and spaces will depend on the target features for enhancement. In the Dutch North Sea, increased surface area correlated with increased taxonomic richness and substrate type favored different benthic communities [90]. Ørsted is working to support natural coral growth on the foundations of offshore wind turbines at its Greater Changhua offshore wind farms in Taiwan, via the ReCoral project, in partnership with Penghu Fishery Research Centre [91].

There are a wide variety of potentially 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 biodiversity, social and technical attributes. Early spatial planning and robust ESIA (see section 0) 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, containing a large amount of relevant data [92]. Proportionate baseline data collection and assessment are required to unlock areas for offshore wind development.

The dynamic nature of the marine environment means that a minimum of two years data collection is required to capture inter-annual variation of species abundance and distribution. This should be factored into timescales for offshore wind deployment. Similarly, post-construction monitoring data should be shared to facilitate a clearer understanding of how observed impacts relate to predicted impacts and used for evidence-based revisions to the permitting process. This will likely speed up the decision-making process by reducing uncertainty in assessments for subsequent projects.

Community benefit measures should benefit communities most affected by offshore wind projects. See section 3.10 for more information on community benefit best practice.

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 help balance priorities and maximize positive coexistence of offshore wind and other users.

C. Set policies to manage environmental and social risks through robust ESIA completed to GIIP, including adequate baseline surveys.

D. Deliver community benefit measures for the communities most affected by offshore wind projects.

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

2.6 STAKEHOLDER ENGAGEMENT

Governments undertake stakeholder engagement as part of the implementation of frameworks and delivery support initiatives. The aim of these engagements is to educate the public, relevant bodies and industry about government plans and involve them in the design of their implementation. Successful stakeholder engagement processes facilitate meaningful dialogue and feedback which reduce misinformation and ensure the credibility of a process and its results. Developers also conduct project-specific stakeholder engagement during their project development activities.

Planning stakeholder engagement

Engagement should start early and continue regularly. Early engagement is essential to ensure the knowledge and interests of stakeholders are considered and incorporated within decision making from the beginning of each process. Continued engagement provides stakeholders with the opportunity to input regularly, maintaining interest and building understanding and trust.

Each stakeholder engagement process should be aligned with good practice principles. Good practice principles include those set out in IFC Performance Standard 1 [93] the International Association for Public Participation (IAP2) Core Values [94] and Spectrum of Public Participation [95]. It is important that engagement processes are tailored to suit local norms and cultures, and that market-specific procedures and regulations are considered.

Stakeholder engagement typically begins with stakeholder mapping which identifies the individuals and organizations with which it will be most important and useful to engage. There should be representation for each of the stakeholder groups impacted to ensure the process is inclusive. It is often useful to map the interactions between stakeholders as this can influence the design of a process. Relevant stakeholders may change, depending on purpose and stage of engagement. The mapping process should recognize this.

It is important to be clear about the context, purpose and timing of engagement. By setting out a timetable and the objectives for each stage of engagement, stakeholders can understand what is expected of them which allows them to contribute appropriately. Timetables should be designed to engage with stakeholders at the appropriate time and allow for sufficient time for meaningful consultation recognizing that it can take time for stakeholder groups to fully engage.

Best practice in stakeholder communication

The method of communication should be carefully considered to ensure that all relevant stakeholders are given an opportunity to input. This should respect the diversity of stakeholders and be adaptable, as different methods work for different stakeholder groups. The range of communication channels include e-mail, face-to-face and hybrid workshops, newsletters, social media, webinars and websites. Face-to-face workshops are typically encouraged to help facilitate constructive dialogue between local stakeholders, while remote methods can be applied to make the process accessible to wider audiences. Consideration should be given to stakeholder access to the internet and digital infrastructure and well as understanding of content and language capability.

Materials should be developed and made available to stakeholders prior to consultation events to prepare stakeholders so they are able to meaningfully contribute. There may be a need to develop introductory, capability building and background information to educate stakeholders since offshore wind knowledge will vary between stakeholders. Documentation setting out the approach, objectives, timetable and technical detail should aim to establish a common understanding of the process and be accessible so that stakeholders can easily engage with the material.

Stakeholders should be informed about how their views have been accounted for within the decision-making process. This should be included within the timeline so that stakeholders understand how and when they receive a response to their input. If the organization leading the stakeholder engagement process chooses not to action or account for certain inputs, it should clearly justify the rationale behind this decision.

Key success factors

Relating to stakeholder engagement, governments should:

A. Engage early and continue regular engagements with key stakeholders across public, industry, and relevant bodies.

B. Set out a clear and transparent engagement plan at the outset, which identifies target stakeholders and provides forward visibility of when and how they will be asked to contribute their views.

C. Tailor communication styles to recognize the different needs and levels of expertise within different stakeholder groups.

D. Provide clear feedback on the outcomes of stakeholder engagement activities and how stakeholder views have been accounted for in the governments' decision making.

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

CHAPTER THREE: FRAMEWORKS

Photo credit: Vestas

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 raise another series of questions for civil servants to address:

- What different frameworks are needed for offshore wind compared to the needs of other energy technologies?
- 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 there be and how can they be managed?
- How can the needs of different stakeholders be managed to maximize co-existence, reduce conflicts and improve acceptance?
- What revenue support is needed and how can this help deliver on policy 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 frameworks help attract relevant developers, lenders, and suppliers 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, shown in Figure 3.1, which are needed to deliver an offshore wind industry.

FIGURE 3.1: FRAMEWORKS REQUIRED TO DELIVER AN OFFSHORE WIND INDUSTRY

Marine Spatial Planning
Deciding in broad terms where it is most beneficial to site offshore wind projects, taking a holistic view of marine resources, avoiding areas of high environmental and social risk.

Leasing
Giving rights to a project developer to survey a potential site, then eventually to construct and operate a wind farm.

Permitting
Providing permissions for a project developer to survey, construct, and operate a wind farm, following a robust Environmental and Social Impact Assessment (ESIA).

Offtake and Revenue
Lowering the risk of the revenue stream sufficiently to enable a final investment decision to be made by investors.

Export Systems and Grid Connection
Enabling timely and cost-effective grid connections.

Health and Safety
Keeping workers safe on industrial-scale projects both offshore and onshore.

Standards and Certification
The confirmation of the engineering suitability of a new wind farm.

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 seabed rights, permits, a grid connection, and some form of revenue support are provided before reaching a final investment decision to construct. In parallel, projects work under health and safety and certification frameworks. Good frameworks also provide stakeholders confidence that environmental, social, or other concerns will be properly addressed.

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 seabed rights allocation, through supply chain contracting and revenue support, to enduring obligations including decommissioning.

There is no single "right" way to organize 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, potentially for other energy technologies, is helpful. For example, many countries already have frameworks for the delivery of onshore wind that can potentially be adapted.

Typically, given the scale of offshore wind projects, 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. 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.

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 England where leasing (The Crown Estate), permitting (the Planning Inspectorate) and revenue support (Department for Energy Security and Net Zero) are all administered by different organizations. The benefit of a one-stop shop is the ease of communication and good coordination between frameworks however it requires adequate and dedicated resources otherwise it can lead to delays. This is especially suited to smaller nations with fewer interactions between different industries. A benefit of having different administrative bodies is that the role, responsibilities and intent of each can be defined.

CASE STUDY 3.1

The Role of One-Stop Shops Covering a Range of Frameworks

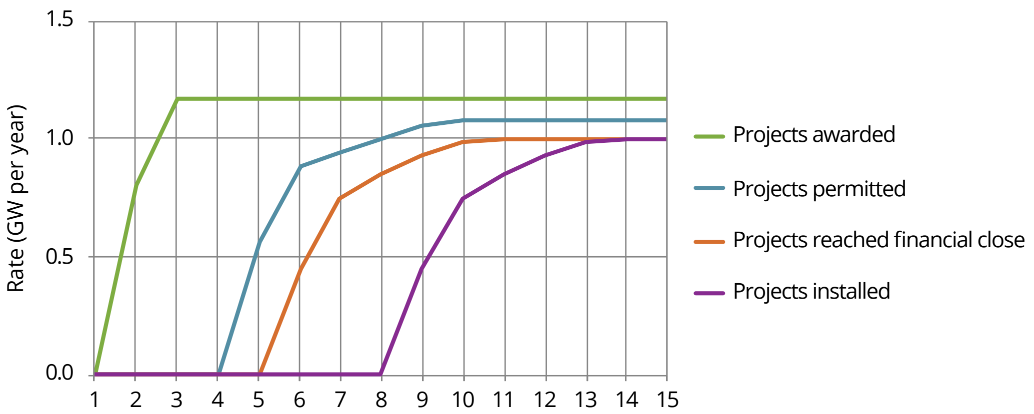
The Danish Energy Agency (DEA) [96] is a good example of a one-stop shop covering multiple frameworks. It has responsibility for public policy, marine spatial planning, seabed leasing, permitting, and offshore wind innovation. Although the DEA does not provide revenue support, it does administer revenue support awards. The competitive process in Denmark combines leasing and revenue support.

The Netherlands Enterprise Agency (RVO) [97] 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 seabed rights, 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 43-50 GW of offshore wind by 2030, set by the Department for Energy Security and Net Zero (DESNZ). The UK Government runs revenue support auctions every year where volumes can be capped by capacity or revenue support budgets. It will only meet its targets if sufficient seabed rights are made available at the right time, recognizing that some awarded capacity may not end up being delivered.[24] 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 to ensure the right size pipeline of projects is provided. Likewise, the Planning Inspectorate, administering the permitting framework, needs to plan its resources for the volume of projects seeking permits. 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, assuming a two-competition model (for seabed rights award and later, revenue support award).

FIGURE 3.2: APPROXIMATE VOLUME THAT NEEDS TO PASS THROUGH FRAMEWORKS EACH YEAR TO ESTABLISH A 1 GW PER YEAR PIPELINE



Creating and improving frameworks takes considerable 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. Managing and administering the frameworks is an ongoing and resource intensive process. Resources need to be planned for and certain mechanism can be used to share this financial burden with prospective developers.

24 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.

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 [98]. Challenges to permitting can also halt projects. This occurred in 2021 to the Guanyin offshore wind farm in Taiwan, China, where the project was unexpectedly denied civil aviation clearance after the project developer had invested significant development capital [99].

CASE STUDY 3.2

French Offshore Experience

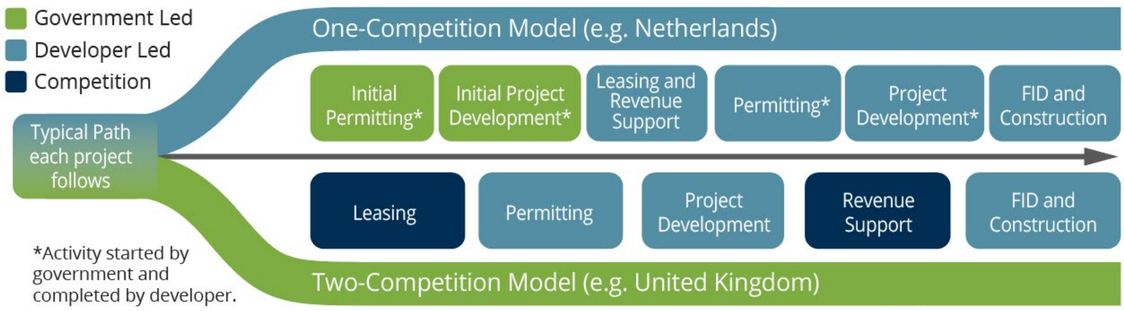
France launched its first offshore wind tender in 2011, followed by another round in 2012, both using existing frameworks which proved inadequate for offshore wind. It was only in 2019 that the first project successfully closed financing. By then, neighboring countries had multiple GW of installed capacity. Many factors contributed to this delay, but the inadequacies of legal and permitting frameworks were key [100] [101].

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 into 2025, France was growing its domestic offshore wind industry through a large tender program. [102]

How frameworks fit together

Different countries operate different timing of seabed rights 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



Note: FID = final investment decision

Considerations

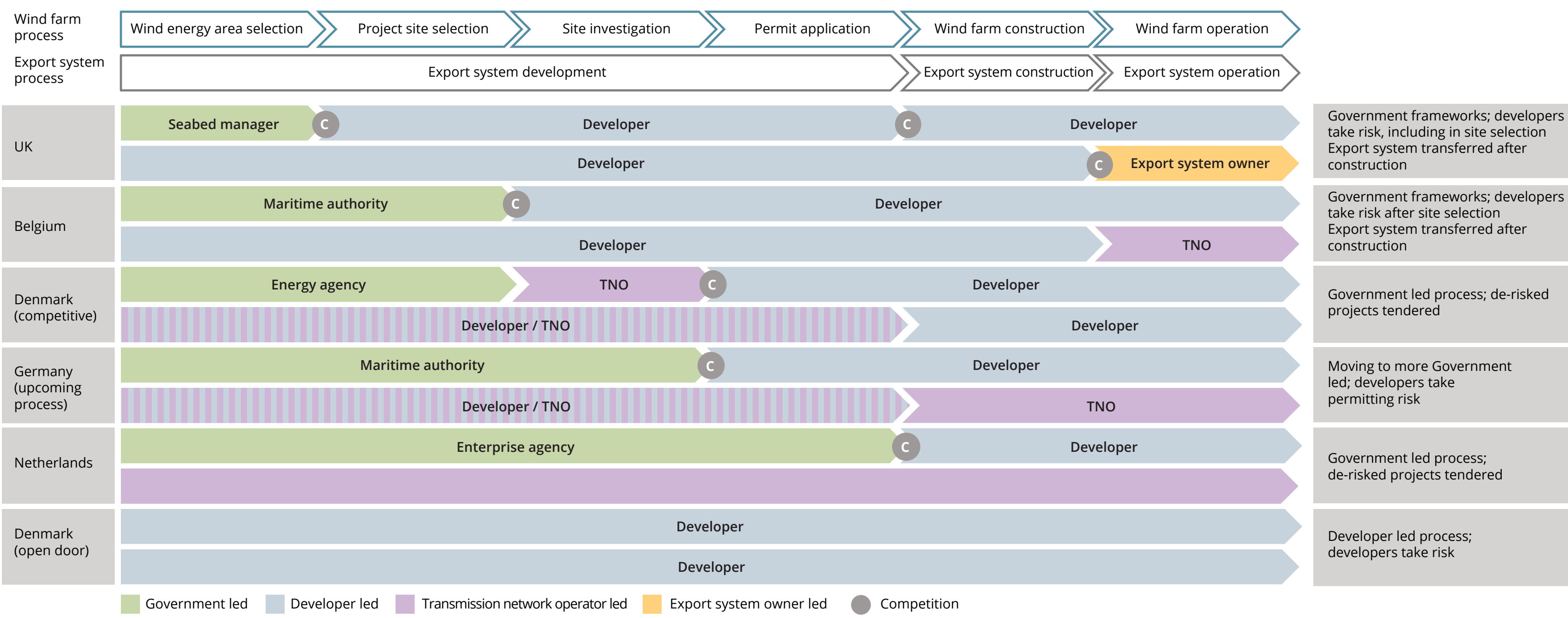
One-competition model (compared to two-competition model):

- 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 developersand local supply chain.
  - Less opportunity for project innovation.
  - Developers do not carry risk of failing to secure revenue support.

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, China, the UK, and the US, governments prefer industry to take ownership of the development process from the start and assume the associated risks. Examples of different government, developer, and transmission network operator roles in established markets are presented in Figure 3.4 (adapted from [103]).

Generally, a two-competition model is likely to be easier to implement for most emerging offshore wind markets. A one-competition model requires significant resource and expertise on the part of government to effectively undertake early project development activities. If governments lack the required capabilities, pursuing a one-competition model can lead to delay and delivery risk. For countries without established offshore wind expertise within government, a two-competition model can derisk the process by placing these activities with developers, who can bring to bear their international expertise to deliver efficient outcomes.

FIGURE 3.4: DIFFERENT GOVERNMENT, DEVELOPER, AND TRANSMISSION NETWORK OPERATOR ROLES IN ESTABLISHED MARKETS



The choice of model is important, but strong definition and capable, well-resourced 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 3.2 to 3.10), and support from experienced consulting firms will be important in finalizing plans. The offshore wind industry is still relatively young, and new experience will continue to be shared, leading to an evolving best practice.

In a competitive market, seabed rights 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 seabed rights 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 is typically carried out through a pre-qualification process prior to any bid price assessment.

Industry engagement to develop frameworks

Significant collaboration between industry, governments, and wider stakeholders is needed to develop robust, effective frameworks. Industry needs to be involved in shaping frameworks for it to be comfortable with the risks associated with investments in offshore wind. 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 shaping 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

UK—Offshore Wind Industry Council (OWIC) [36]

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 [34] in which UK 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 2.2.

Japan—Public-Private Council on the Enhancement of Industrial Competitiveness for Offshore Wind Power Generation [61]

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 discussed 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 2020, 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, well -resourced 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 seabed rights allocation framework and as an early input to the permitting process for projects, marine spatial planning (MSP), delivered in a proportionate and pragmatic manner[25], can make a significant contribution to the timely, strategic deployment of offshore wind.

Offshore wind MSP involves mapping, with stakeholder engagement, the sensitivity of a wide range of biodiversity, social, and technical attributes to offshore wind, then considering cost of energy, transmission network and location of demand to establish a plan for where (and, as an extension, when) offshore wind development should be supported.

The sustainable use of marine resources is mandated by international agreements and captured in the United Nations Sustainable Development Goals (UN SDGs) [104]**.** As offshore wind projects form nationally important infrastructure, it is good practice that a strategic approach is taken to inform their location. MSP enables a government to be clear about its priorities. Blue economy [105] and sustainable ocean economy [106] 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.

25 The amount of activity related to an MSP will vary. Proportionate and pragmatic delivery means:
- For an early-stage MSP in an emerging market, a simplified assessment may be preferable to help set the direction of the industry using the limited knowledge and data available rather than taking many years to do a detailed study.
- For a more established market with much knowledge and data available, a more detailed study giving increased confidence is likely to be better.

The judgement in each case is about the benefit and viability of a deeper study recognising the availability of information, how the study will be used and the scale and significance of potential impacts.

CASE STUDY 3.4

Sustainable Ocean Economy

Commitments have been made by 18 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 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 [106].

Sustainable ocean management is guided by the Sustainable Ocean Plans framework [107]. 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 seabed awards for offshore wind is effective in reducing project risk when the MSP can be conducted in a sufficiently robust and efficient manner. It helps reduce conflicts with other users of the sea and the risk of adverse biodiversity and social impacts. It also reduces permitting risks faced by individual projects, thereby increasing confidence in the market and attracting experienced project developers and international sources of finance.

MSP does not replace permitting, but it does make it a more predictable process. MSP considers biodiversity, social, and technical attributes at a high level over a wide area and helps to consider cumulative impacts of several projects in an area. The permitting process for a given project is then conducted at a deeper level, requiring consideration of more local and site-specific factors within a specific project design envelope. International Union for Conservation of Nature (IUCN) has published early guidance on biodiversity cumulative impact assessment for offshore wind [80].

Governments are in the best place to establish how to balance the use of the marine space within their Exclusive Economic Zones (EEZs)[26] and to lead MSP development. 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.

The most holistic approach to MSP involves collaboration between countries. Although this is not always possible or necessary, it is a good target as volumes of offshore wind increase, especially into the next decade. 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 [108], possibly because the requirements for European Union (EU) 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.

Limited resources or time pressure may mean that it may not be possible to develop a full, multisectoral, marine spatial plan. In these circumstances and given significant offshore wind technical potential in emerging market countries and the need to meet climate targets and establish energy security, environmental and social (E&S) sensitivity mapping offers a pragmatic and proportionate approach to guide early spatial planning for the sector. This type of an approach can be rolled out at scale in an accelerated timeframe. It can serve as a precursor to, and is compatible with, MSP initiatives.

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.

26 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.

Case Study 3.5 Continued

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 [109]. 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 [110]. Again, while this is beneficial, it is important to keep near-term projects on course while taking a longer-term strategic view.

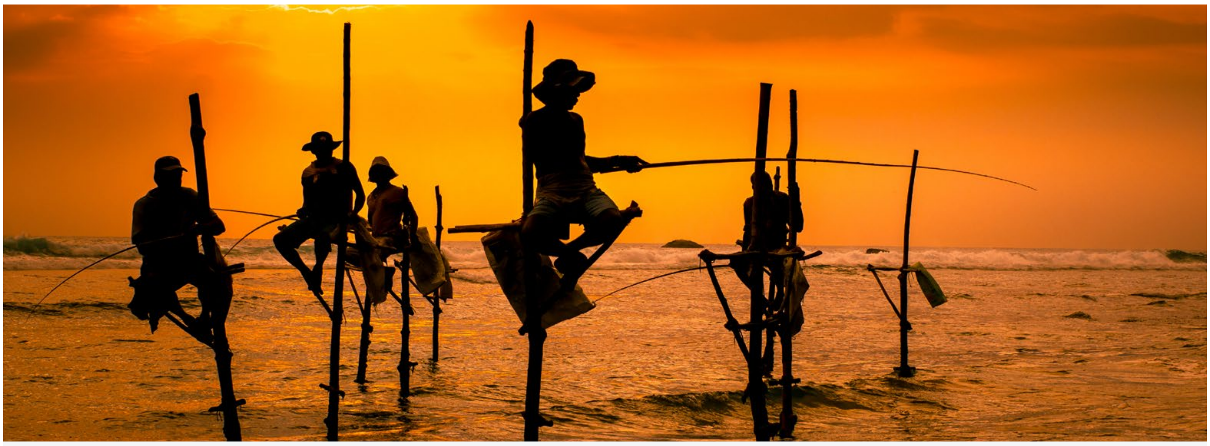
At a local level, in September 2020 eight countries around the Baltic Sea, in northern Europe, signed a joint declaration with the European Commission to accelerate offshore wind, with an early focus on collaborative MSP [111].

Collaboration in MSP stretches well beyond offshore wind [112]. Bulgaria and Romania have for a long time collaborated on a joint MSP [113].

Although many EU members states are working on second or third iterations of their multi-sector spatial plans, there is still much work to do to fully incorporate offshore wind sensitivity mapping into data sets to enable most effective planning of future offshore wind development.

Principles of marine spatial planning

The principles of MSP can be followed, and a collaborative process be managed with a minimum level of data available. Such MSP can then be refined over time as more data becomes available. The Intergovernmental Oceanographic Commission (IOC) has provided well established guidelines for MSP [75], including a step-by-step approach [114]. The World Bank has published Integrated Environmental and Social Sensitivity Mapping — Guidance for Early Offshore Wind Spatial Planning (SenMap), building on its environmental and social standards [115] [116] (see Case Study 3.6). IUCN has also published guidance for spatial planning of renewables [117].



CASE STUDY 3.6

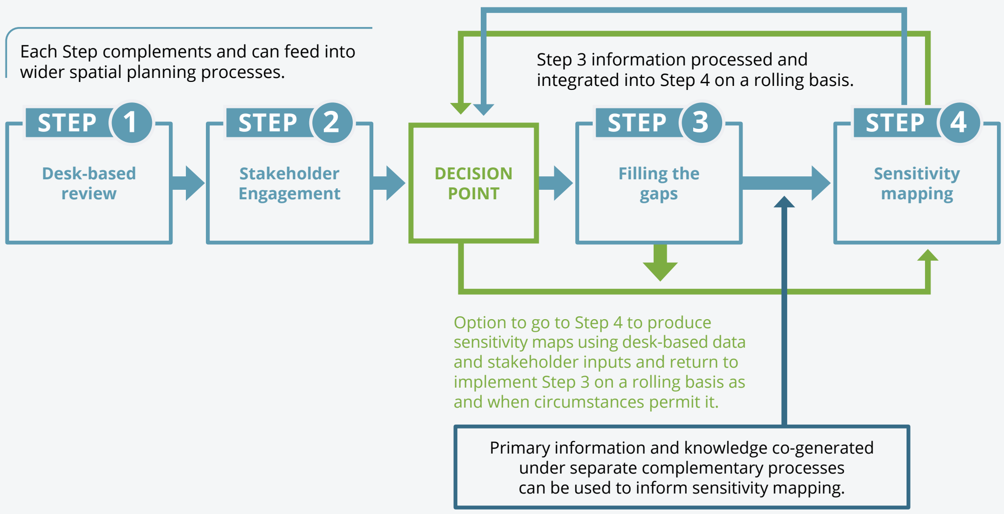
Guidance for Early Offshore Wind Spatial Planning (SenMap) [115]

SenMap was designed to support government planners in emerging market countries to identify potential areas for offshore wind development with lower E&S sensitivities. The resulting outputs—E&S sensitivity maps—can help identify broad potential development areas for offshore wind, at the earliest stages of government-led spatial planning. Sensitivity maps can support planning for avoidance, directing development away from areas where sensitivity is highest. While primarily a government-led planning tool, SenMap can also be used by developers to inform the start of project-specific environmental and social impact assessment.

The first uses of SenMap were in national offshore wind spatial planning activities in Viet Nam and the Philippines—see Case Study 3.7.

The principles and practice of SenMap underpin Section 3.3 of this report. See Figure 3.5 for a summary of the SenMap methodology.

FIGURE 3.5 SENMAP: A FLEXIBLE APPROACH TO SENSITIVITY MAPPING



Sensitivity mapping is especially relevant in emerging markets where regional-scale E&S data is often lacking. SenMap is a useful way to identify key data gaps and target studies to focus on the highest risk factors at the regional-scale early in the development process. For more details, see Case Study 3.7.

Often, a full, multisectoral, marine spatial plan is not available to incorporate offshore wind into national planning processes. Rather than waiting for such a plan, offshore wind-specific MSP can still deliver significant benefits. The first iteration of such offshore wind planning in an emerging market is likely to have limitations but can help bring relevant stakeholders together and accelerate understanding of the sector and the key biodiversity, social and technical considerations in a given market, enabling further studies and stakeholder dialogue in time.

The key principles of SenMap are designed to enable a balanced, fair and inclusive process. They include:

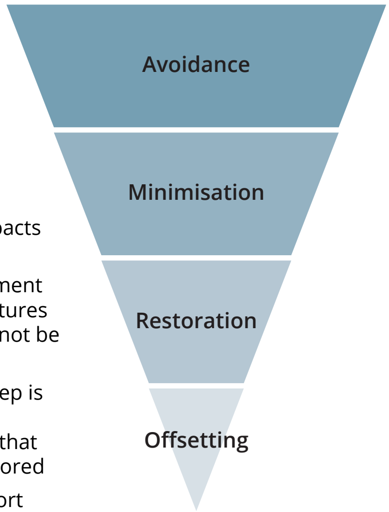
- The mitigation hierarchy (an ordered list of steps to reduce the impacts of offshore wind as low as feasibly possible, see Figure 3.6).
- The precautionary principle which places emphasis on avoiding actions with potentially harmful (and particularly irreversible) consequences until there is sufficient information available to properly assess and weigh the likely costs and benefits [118].[27]
- A gender-based and participatory approach.
- Knowledge co-generation (for example, involving diverse types of expertise, knowledge, and actors).
- Proportionality, pragmatism and flexibility to be tailored to the country context.

FIGURE 3.6: THE MITIGATION HIERARCHY TO REDUCE THE IMPACTS OF OFFSHORE WIND

The mitigation hierarchy aims to reduce the impacts of offshore wind as low as feasibly possible through:

- **Avoidance** – the first important and most effective step is to anticipate and prevent impacts
- **Minimisation** – the next step is to implement measures to reduce the duration, intensity, and/or extent of impacts that cannot be completely avoided
- **Restoration** – the third step is to implement measures that aim to repair specific features damaged by project impacts that could not be completely avoided or minimised
- **Offsetting** – the last and least certain step is to implement measures to compensate for significant adverse residual impacts that could not be avoided, minimised or restored

Offsets should be a measure of last resort



27 In addition to data from biodiversity surveys, advice from technical experts and stakeholder consultations should be used to determine what information is sufficient for decision making (see ESS6, Guidance Note paras. GN 12.2 and 12.3) [118].

CASE STUDY 3.7

Experience of early offshore wind spatial planning in the Philippines and Viet Nam

In 2024, two early uses of SenMap were to guide national offshore wind spatial planning projects delivered for the governments in the Philippines and Viet Nam [119] [120], building on World Bank roadmaps [121] [6]. This included consideration of the following:

Biodiversity
Seabirds
Migratory birds
Other resident bird species
Bats
Other terrestrial flora and fauna
Marine mammals
Fish
Marine turtles
Other Red List species
Protected, Recognized and Designated Areas
Coral reefs
Mangroves
Seagrass

Social
Aquaculture and fisheries
Coastal communities and Indigenous peoples
Wreck sites
UNESCO World Heritage Sites
Historical landmarks and local cultural sites
Registered underwater cultural heritage
Landscape and seascape
Tourist attractions and ecotourism areas
Dive sites

Technical
Water depth
Seismic activity
Extreme gust wind speed
Sea currents and wave heights
Civil aviation
Oil and gas infrastructure
Submarine cables
Shipping lanes
Other vessel activity
Military areas
Aggregate and material extraction areas
Offshore disposal sites
Unexploded ordnance
Bridges and causeways
Levelized cost of energy

The development of a sensitivity map can highlight areas of relatively lower or higher sensitivity, as well as areas of highest sensitivity that are unsuitable for offshore wind development and should be avoided. This approach helps to reduce risk of harm, manage project risks and avoid the potential for significant and costly delays later in the development timeline. The results can also highlight areas that would require longer baseline survey periods to factor in to the environmental and social impact assessment (ESIA) at the project level (see Section 3.5). Results could also be used to inform strategic planning of offshore wind and transmission upgrades and competitive auctions with respect to the scale of E&S mitigation that might be required in higher risk areas.

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 example, see work published by WindEurope [122] [43]). Economic viability considers key drivers of LCOE such as wind resource, water depth, distance to construction port, grid connection, and onshore transmission network upgrades. This can help to focus the spatial planning process by identifying the relevant areas for environmental social and technical data collection and assessments. It therefore helps to minimize time and efforts spent assessing sites that will not ultimately be economical.

A good understanding of spatial sensitivities, economic viability and the location of future energy demand is a strong basis for moving to competitively awarding seabed exclusivity. Typically, before award, a government will:

- Decide on desired order of build-out of project clusters, especially considering requirements for transmission network upgrades.
- Conduct further strategic environmental and social assessment work to develop and refine the understanding of risk and sensitivity for a given potential cluster of sites to be awarded.

- Conduct relevant baseline or regional-level surveys in response to the outcomes of the MSP, but not detailed, project-specific surveys (unless a single-competition model is being followed, ref. section 3.2).
- Address key high level data gaps identified in early MSP. This could involve targeted primary data collection and further detailed engagement with relevant specialist stakeholders for a given attribute.
- Conduct a cumulative impact assessment (CIA) for given clusters of projects. Guidance on CIA for wind (and solar) developments and associated infrastructure was published by the International Union for Conservation of Nature (IUCN) in 2023 outlining a pragmatic and scalable entry-point (initially desk-based) approach to CIA by government planners [80].
- Maximize the bankability of projects before they are awarded through a competitive process through providing robust frameworks for seabed rights, permitting, offtake and revenue and export system and grid connection.

To minimize the risk of conflict and delays, offshore wind spatial planning should be conducted before awarding exclusivity rights for project sites. Where rights to sites have been awarded first, governments are encouraged to address issues arising proactively, rather than leaving them to the market to address.

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

Making MSP data and other government-led survey results available to relevant stakeholders and project developers improves transparency and the efficiency of seabed rights allocation and permitting processes. Where necessary, governments can request the release of more commercially sensitive data from prospective developers as part of the MSP process subject to confidentiality restrictions and allow 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. Regular engagements are 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 3.10 (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 stakeholders are included in the engagement. While there is good practice , 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 3.8.


Photo credit: Vestas

CASE STUDY 3.8

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.

In 2022, 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 [123].

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 seabed rights 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 SEABED RIGHTS

To enable the necessary investment, project developers will 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, a permit, a contract or a concession.

The right to issue seabed rights

Each country owns territorial waters that span 12 nautical miles beyond its shoreline, but it can claim sovereign rights in an EEZ that extends up to 200 nautical miles from shore. The United Nations Convention on the Law of the Sea (UNCLOS) is recognized by most governments [124]. 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 issuance of rights over sea areas for offshore wind projects. Developers will require seabed rights, underpinned by law, to provide the rights to explore, develop, construct, and operate a project. These exclusive rights give the certainty needed by investors to commit funds to project development and delivery. This legislation should also identify the party responsible for awarding seabed rights. 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 seabed rights for offshore wind, but it is important that the award process and seabed rights themselves both account for the specific requirements of offshore wind.

Seabed rights award formats

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

- **An ad hoc bilateral process, where a developer asks for a seabed rights:**[28] The request is assessed and, if seabed rights are granted, then it is likely to have time-bound conditions applied, for example, environmental surveys must be completed within three years of award. Some emerging markets have used this way for early projects to be progressed, as has been the case in the Philippines [125] and Viet Nam [126] however it can be challenging for governments to maintain strategic control on the allocation process. It has also been used in the UK for innovative projects under 100 MW [127] and early example floating projects [128], and was an option in Denmark for any scale project for some years [129]. Bilateral agreements do not provide transparency or enable a competitive market and hence are unlikely to offer long-term value to electricity consumers however, and therefore do not represent an optimal solution. This arrangement was stopped in Denmark over fears of EU rules breach relating to lack of competition [130].
- **Seabed rights price-based competition:** highest price bidder per km^2 wins as in the UK Leasing Round 4. This approach can be mixed with some qualitative criteria as in ScotWind but remains primarily price driven.
- **Seabed rights selection-based competition:** A separate, stand-alone competitive process, providing exclusive rights to the developer with most merits on a range of criteria, as in Colombia and Australia.
- **Electricity price-based competition** (one-competition model) allocating rights combined with revenue support (see Figure 3.3). In this process a developer is awarded both seabed rights, and sometimes other permits, and a commitment to revenue support at the same time, as in the Netherlands, France and Denmark.

Certainty of tenure is important from an early stage in a two-stage allocation process. This means that a developer, and any investor it brings on board, has confidence that no other party will be able to take over the site against its will. The precise legal vehicle of seabed rights 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.
- Exclusive seabed rights (in the form of a permit, a contract or concession for instance) as in Australia, Colombia and the Philippines.

28 Lease is used here 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 seabed rights 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, seabed rights are being issued to cover over 50 years (even up to 80 years), which can enable project life extension[29] or repowering,[30] allowing developers to plan beyond the current typical 25 to 30-year operating life of offshore wind turbines. Such detail likely will depend on national practices in similar situations. However ensured, it is critical that the seabed rights be considered bankable.

A range of approaches have emerged to the design of framework for awarding seabed rights. Key considerations regarding timing of seabed rights competitions are discussed in Figure 3.3. Pros and cons of three different seabed rights processes are summarized in Table 3.1. To help show the range of leasing activities used, examples of seabed rights processes are shown in Case Study 3.9. If the competition involves bidding seabed rights fees, then it is relevant to note that higher seabed rights fees are likely to eventually be reflected in higher consumer bills, as such costs are passed on to consumers through the tariff. High fees may also price smaller developers out of the market if they are not able to risk large amounts just to access seabed rights on a single site, with no certainty of ultimately winning revenue support.

Markets benefit from a pipeline of projects, so it is helpful to have a seabed rights 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 of projects in development that is beneficial for the supply chain and the local workforce.

Seabed rights processes should be transparent, robust, and repeatable, and should encourage timely project development. It is important to set a clear process for obtaining seabed rights with defined criteria for establishing who will be awarded rights. This gives project developers the ability to assess their chances of obtaining rights, and to consider investing in the process. These features also minimize the risk of legal objections to awards. It is critical for a project developer to have confidence that their investments will not be negated by losing their seabed rights. Developers recognize that they need to take a level of development risk relating to permitting, wind resource and offtake, but confidence is undermined if the seabed rights process is challenged, and decisions are changed.

It is important to continue to monitor seabed rights to ensure processes are delivering suitable volumes of projects and are following evolving international good practice. Seabed rights are 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 awarded 8 to 10 years earlier, as shown in Figure 3.2. Whatever arrangement is chosen, it is likely that changes will be needed over time to deliver policy outcomes.

It is important that seabed rights 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 likely to be economically viable. Typically, governments in established markets use the results of MSP to help define potential development areas. Some governments, such as in Colombia and Japan, have limited the number of sites which can be allocated to any one developer in an auction, to ensure industry diversification and reduce non-delivery risk associated with reliance on any single entity.

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

30 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.

Seabed rights 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 seabed rights competition, as the risk of overlapping sites is avoided; it also potentially simplifies later permitting activity, as locations can be chosen to reduce 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 seabed rights competitions are provided in Figure 3.7.

FIGURE 3.7: EXAMPLES OF SPECIFIC SITES (NEW YORK BIGHT) AND LARGE AREAS (UK ROUND 4) FOR LEASE COMPETITIONS

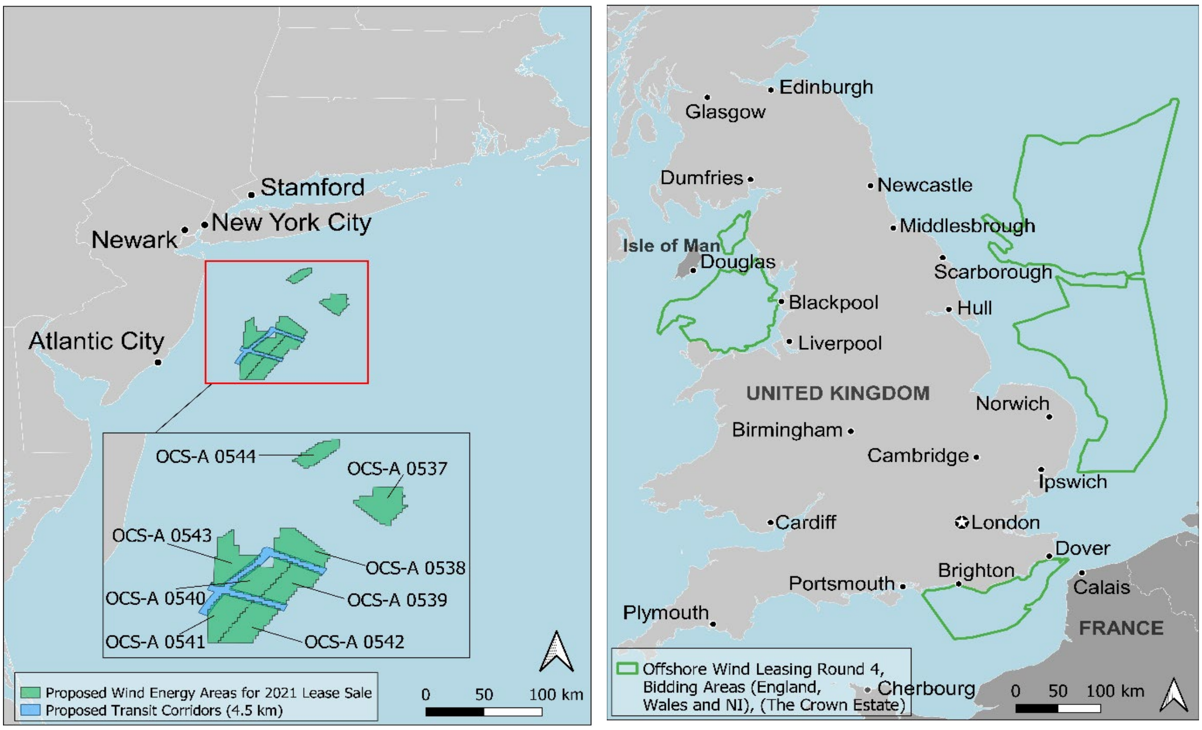


TABLE 3.1: COMPARISON OF DIFFERENT FORMATS FOR SEABED RIGHTS AWARDS

	1. Bilateral	2. Seabed rights price-based competition (as part of two-competition model)	3. Seabed rights selection-based competition (as part of two-competition model)	4. Seabed rights and revenue support electricity price-based competition (one-competition model)
Description	Ad hoc agreement between individual developer and seabed authority.	Competition to award seabed rights based upon the highest price per km^2. Competition held early in the project development lifecycle, with any revenue support competition run separately, after permitting. Price may be absolute or per year during development.	Competition to award seabed rights based upon value factors to identify the developer with the most merit. Competition held early in the project development lifecycle, with any revenue support competition run separately, after permitting.	Competition to award seabed rights and revenue support based upon electricity price. Competition held late in the project development lifecycle.
Activities	**Seabed rights body:** Responds to request and assesses, in isolation to other potential future requests. **Developer:** Early-stage project development to determine site. **Both:** Negotiate terms. **After award:** Developer progresses all stages of project development — design, permitting, purchasing, and construction.	**Seabed rights body:** Decides areas to be awarded, preferably using MSP principles. These could be broad areas (zones) or single-project blocks offering some flexibility in project placement. Also manages competition, providing rules and terms of seabed rights. **Developer:** Responds by assessing areas and bidding following competition rules, with focus on price. **After award:** Winners negotiate details of seabed rights with the terms provided, then progress all stages of project development — design, permitting, purchasing, and construction.	**Seabed rights body:** As option 2. **After award:** As option 2.	**Seabed rights 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 a low risk of surprises during final stage of project design and permitting. Manages competition, providing rules and terms of seabed rights. **Developer:** Responds by assessing sites and bidding following competition rules. **After award:** Winners negotiate details of seabed rights with the terms provided, then progress remaining stages of project development — final design, final permitting, purchasing, and construction.

	1. Bilateral	2. Seabed rights price-based competition (as part of two-competition model)	3. Seabed rights selection-based competition (as part of two-competition model)	4. Seabed rights and revenue support electricity price-based competition (one-competition model)
Pros	Can work well to help accelerate early projects in an emerging market.	Less effort and cost for government than option 4. Maximizes the value of the seabed asset as the Government generates income through the price mechanism. Gives developer more freedom in design of its project than option 4 - developers are better-placed than governments on how to develop lowest LCOE projects. Developer owns project for longer than option 4 -more freedom to speed up/slow down development of any project in their portfolio.	Value factors allow the Government to achieve wider public policy objectives Otherwise, as option 2.	Government in full control of where projects will go, and when they will be constructed. Single competitive process to manage. Government de-risks projects further for project developers by considering permitting in detail (including cumulative effects of multiple projects) before awarding seabed rights.
Cons	Developers have no framework to work within. Multiple developers seeking projects in the same or similar locations can lead to inefficiency through duplicative survey and development work.	Government does not prescribe exactly where projects will go. Increased cost to consumers as price paid for the sites is added to the overall LCOE. Extra process (and risk for developers) for revenue support once developers understand LCOE of project better. More risk to developers relating to permitting.	Government does not prescribe exactly where projects will go. Value factors introduce subjectivity into the competition which is more open to challenge than price-based competitions. Additional complexity of value factors may disincentivize investment and lead to less economically efficient outcomes than a price based competition. Government must monitor and verify the commitments made in the competition, which can be challenging. Extra process (and risk for developers) for revenue support once developers understand LCOE of project better. More risk to developers relating to permitting.	Government must manage early development work, up to seabed rights specific projects. This requires more effort, experience, staff and cost for government (that can be reclaimed from auction winner) than other options. Little opportunity for project developer to make project design decisions or prioritize between projects.
Examples	Korea, the Philippines, Viet Nam (early project(s) only)	Taiwan, China, the UK (England and Wales), the US	Australia, Colombia, the UK (Scotland)	Denmark, France, Germany, the Netherlands

CASE STUDY 3.9

Example seabed rights arrangements in the Netherlands, Taiwan, China, the UK, and the US

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

Netherlands Round 5 (2019—2020) [133]

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. In this auction, after a basic assessment that each bidder could deliver the project within four years, a list of transparent and non-subjective non-price 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, China Phase 2 Transition Round (2018—25)

In 2018, the Taiwan, China Government released 36 zones for potential development of 5.5 GW of offshore wind. 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 capacity was allocated through a selection process based on technical and financial readiness and 1.7 GW was awarded through a price-based bidding process. The selection process used a set of criteria, including stringent local content considerations, to select winning bids. The bidding process awarded sites to the bidders with the lowest offtake tariff, without local content restrictions. Developers wishing to participate in the bidding process had to participate in the selection process and achieve a minimum score to qualify for the bidding process. The outcome was that projects that came through the selection process received more than double the per MWh price compared to those that came through the bidding process.

Case Study 3.9 Continued

There were 13 winning projects developed by six 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 Leasing Round 4 (2020–21) [134]

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, which is typically not a desired outcome for governments.

US federal lease auction for sites off New York (2018) [135]

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 $405 million for 4.1 GW capacity on offer, or approximately $100,000 per MW.

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 seabed rights framework for offshore wind.

Seabed rights processes need to cover cable routes and any other relevant considerations. This can be incorporated into project seabed rights 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 3.23). Seabed rights for cable routes are provided by The Crown Estate but in a noncompetitive arrangement once project seabed rights have been awarded [136]. Seabed rights 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 seabed rights process

Seabed rights need to be administered by a well-resourced, trusted organization. A seabed rights 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 3.10 to help show what sort of organization is best placed to administer leasing.

CASE STUDY 3.10

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 [137], including national and regional guidelines [138].

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 seabed rights, 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 UK Round 4 lease competition and managed a robust, bankable process [134]. Examples of this communication are provided in Figure 3.8 and Figure 3.9.

Successfully and efficiently awarding seabed rights requires careful consideration of:

- Impact of fees bid on the cost of energy.
- Transparent and clear mechanism to avoid or resolve overlapping interests of prospective bidders.

- Risks imposed on developers that may be out of their hands to address (such as penalties for delays, even if due to slow permitting decisions).
- Time and resource requirements on the government of administering a process requiring or allowing bidders to submit lengthy proposals.

FIGURE 3.8: OBJECTIVES OF THE UK ROUND 4 LEASE COMPETITION, AS COMMUNICATED BY THE CROWN ESTATE

- **Delivers a robust pipeline for low-cost offshore wind deployment** to help meet industry appetite and Government policy objectives for new offshore wind capacity, supporting the UK's clean energy transition.
- **Offers an attractive, accessible and fair proposition to developers** at repeatable scale, contributing to the development of a competitive, resilient and innovative offshore wind market.
- **Balances the range of interests in the marine environment** supported by extensive engagement with stakeholders and the promotion of responsible evidence-based site selection.
- **Makes efficient use of the seabed** recognising its value as a national asset, now and for the long term.
- **Unlocks the commercial value of the seabed in line with our statutory obligations** securing best consideration over the long-term, for the benefit of the public finances.

Source: The Crown Estate [132]

FIGURE 3.9: TYPICAL RIGHTS ALLOCATION PROCESS, BASED ON THE CROWN ESTATE'S ROUND 4

Stage 1 **Consideration (3-4 months)**	Stage 2 **Prequalifications questionnaire (PQQ) (3-4 months)**	Stage 3 **Invitation to tender (8-10 months)**	Stage 4 **Award seabed rights**
Aim: The aim of this stage is to ensure potential bidders have all the information required to understand the process and clarify requirements.	**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.	**Aim:** The aim of this stage is to evaluate tender submissions against competition requirements.	**Aim:** The aim of this stage is to award seabed rights to the winners of the competition.
Typical steps: The regulatory body provides all relevant competition information to the market, including objectives, process, timeframes, and rules for the competition. This may include the regulatory body hosting market information days, providing potential bidders an opportunity to ask questions, and directly engaging with the regulatory body.	**Typical steps:** The regulatory body issues a PQQ to the market. Potential bidders respond to the PQQ, and the regulatory body assesses the potential bidder's financial capability, technical experience, and legal compliance. Successful bidders prequalify to the next stage of the competition.	**Typical steps:** The prequalified bidders are invited to submit a tender. The tender is evaluated by the regulatory 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.	**Typical steps:** Winning bidders proceed to negotiate the details and terms of the lease with the regulatory body. Following negotiation, seabed rights are awarded and signed by both parties.

Source: Based on The Crown Estate [132]

The seabed rights 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.

Seabed rights terms

Seabed rights 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 seabed rights holders holding seabed area, or land, without progressing development, as this could slow down the growth of the industry [139]. The lesson learned in the UK is that a few high-level key milestones are sufficient. Permits for seabed rights or agreements for lease[31] 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 seabed rights include the start of project implementation and works completion, tied to commitments made when securing revenue support.

If a government considers including seabed rights fees as in the UK or in the US leasing processes it needs to reflect the government's intent regarding offshore wind. If a seabed rights 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 seabed rights costs built into the process are likely to add to costs when finalizing revenue support. Seabed rights competitions which seek to maximize upfront seabed rights fees can benefit governments by providing immediate revenue, however it is important to recognize that higher seabed rights fees are passed on to the electricity consumer eventually.

Typically, beyond an initial seabed rights 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). This is either a fixed amount per square kilometer (sq km), per megawatt (MW) or per megawatt-hour (MWh) or percentage of gross revenue. Table 3.2 provides examples of rental fees in a number of countries.

31 An agreement for lease places a contractual obligation on the parties to enter into the lease agreement, 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 [140] [141] [133] [142]

Country	Public agency	Project phase/element	Rental	Units
Scotland	Crown Estate Scotland	Operation	£1.07 (US$1.48)	Per MWh[32]
England and Wales	The Crown Estate	Operation	2%	Of gross revenue[33]
Netherlands	The Central Government Real Estate Agency	Operation	€0.98 (US$1.15)	Per MWh[34]
		Construction	€650 (US$763)	Per MW per year
		Array cables	€3.29 (US$3.86)	Per m^2 (single, one-off payment)
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

In some markets, bid bonds are used to discourage speculative bidding practices. Bid bonds are a financial deposit which can be retained by the rights holder in case of non-delivery against certain milestones. They can be a useful tool to ensure developers participating in the seabed rights process have the financial capability to follow through, however if not carefully designed, can act as a disincentive to investment, reducing competition. This is a particular risk in emerging markets where risk and uncertainty are typically higher, and there is increased chance that project delays are due to factors that a developer has no control over. If implementing a bid bond, the size of the required deposit, and the execution triggers which could result in its retention, should be carefully considered and transparently published.

Seabed rights periods need to reflect project development and operation timescales. It typically 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 and as technology matures, operating life is increasing. In most markets, new seabed rights allow for 25 to 30 years of operation. 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 [139]. 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.

Agreements for lease or seabed rights 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 made available through the Marine Data Exchange [92]. 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 [143]. The data are valuable in reporting industry-level H&S performance, which in turn sets priorities for areas of improvement.

32 Price is index linked.
33 Eighty percent minimum output.
34 For area within 12 nautical miles, index linked.

Seabed rights 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 [144].

Key success factors

Related to seabed rights for offshore wind, governments should:

A. Set out a transparent, robust, and repeatable seabed rights process.

B. Ensure seabed rights is administered by a well-resourced, trusted organization for timely, bankable outcomes.

C. Monitor seabed rights 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 the following elements which can take different forms depending on the country; these typically start after project rights award (site exclusivity):

- Approval to carry out surveys.
- Environmental and social approval following the environmental and social impact assessment (ESIA) (including an appropriate period of baseline surveys) and the required stakeholder engagement steps.
- Approval for construction and operation.

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 [145] [146]. Even when governments award 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 and cost to consumers.

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 [147] and World Bank ESS6 [116], 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.[35] Aligning permitting 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 advanced, thereby reducing risk.

Administering the permitting process

Permitting needs to be administered by a well-resourced, trusted organization. Permitting for construction and operation of 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 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 permitting process moving to agreed timescales.
- 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.[36]
- Administer any appeals process.

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

36 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.).

An example of an organization that plays this role well is the Planning Inspectorate (PINS) [148] in the UK (see Case Study 3.11 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 3.11

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 offshore wind projects can be found on the PINS website [148].

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 [149]. At the end of the period, PINS makes a recommendation to the 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.

The permitting process for offshore wind projects should cover all assets needed to be developed, built and owned by the developer at any stage, from onshore to offshore. A single permitting activity for all assets can help streamline the process and avoid risk of timing mismatch between part of the project permitting. For onshore infrastructure, robust and proven wayleave and compulsory purchase processes are important.

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) TAIWAN, CHINA AND US

	1. Netherlands	2. UK (England and Wales)	3. Taiwan, China	4. US
Description	Process led by the Netherlands Enterprise Agency (RVO) prior to lease competition, then completed by developer once design finalized. Export system addressed separately, as 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 export system.	Process led by developer that prepares application once it has obtained an offtake agreement with the Bureau of Energy (BOE) and a grid connection agreement from grid operator Taiwan Power Company.	Process led by developer that prepares application once it has lease and engages with wide range of federal, state, and local bodies.
Permitting authority	Ministry for Economic Affairs and Climate Policy issues permits.	Planning Inspectorate (PINS) administers process, coordinating with all relevant stakeholders.	The Establishment Permit (EP) is issued by the BOE.	BOEM approves Site Assessment Plan (SAP) and Construction and Operation Plan (COP).
Activities	**Government:** RVO submits all relevant documentation following surveys and consultation activities. **Government:** Ministry for Economic Affairs and Climate Policy makes preliminary decision. **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:** 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 Department for Energy Security and Net Zero makes final decision based on recommendations.	**Developer:** Needs to obtain the final EIA approval from the Environmental Protection Administration (EPA) before applying for the EP. To obtain the EP, the developer must obtain consent letters from various authorities The EP is valid for a period of three years and may be extended for a further two years. **Government:** BOE makes final decision.	**Developer:** Submits relevant documentation, following surveys and consultation activities. **Permitting bodies:** BOEM 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 export system. **Federal government:** Makes final decision based on recommendations from BOEM. **State government:** Makes final decisions regarding export system.

	1. Netherlands	2. UK (England and Wales)	3. Taiwan, China	4. US
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.	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 activities 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.	Consistent and well documented process.	BOEM has responsibility for leasing and permitting, enabling some synergies and continuity of communication. BOEM part of process is the same for each state.
Cons	Upfront costs to government to undertake studies and plan project areas. Cost to maintain capability and resources within government. Developers are often better than government at selecting and designing sites, and at taking advantage of innovation that can lead to cost reductions.	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.	Complex and lengthy process, requiring engagement with many different governmental bodies. The processing time for the various consent letters required varies and may be unpredictable.	Complex process with variations depending on location, especially regarding export system. Range of stakeholders for developer to engage with.

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 (as well as the environment), decisions need to be based on clear criteria. Examples of good practice in this area are the list of regulations presented by PINS in the UK [150] and BOEM in the US [138]. A clear process helps stakeholder concerns to be addressed at an early stage [149]. It also helps ensure that projects are built in a way that best meets the needs of all stakeholders.

Where existing policy commitments relevant to offshore wind are in place, it is important that specific mechanisms be implemented for these policies to be considered in permitting decisions. One example is renewable energy to facilitate carbon emissions 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 provides the ability to permit a project without fixing every detail [151]. 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 turbine models or 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. In addition, 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 on baseline survey results, original ESIAs, 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 3.13), but this relies on timely responses from stakeholders.

Environmental and social impact assessment

An ESIA is a review of the various possible environmental and social consequences of a new infrastructure project and their magnitudes. In most markets, all offshore wind projects require an ESIA as part of a developer's permit application. The completion of an ESIA meeting international standards is a fundamental requirement for most international lenders. Including a legal or regulatory requirement for ESIA to be carried out in accordance with GIIP helps build confidence in timely offshore wind deployment. For example, see the World Bank's Environmental and Social Standards (ESS) [116] and the International Finance Corporation's Performance Standards (IFC PS) [93]. 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.

Delivering ESIAs consistent with international standards 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 occurred for projects in Taiwan, China and Viet Nam. 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. 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 3.12. 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 3.12

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 (2019) [147] 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. For example, over 120 financial institutions are signatories to the Equator Principles, a financing benchmark for determining, assessing and managing E&S risk. Signatories agree to apply IFC Performance Standards and the World Bank Group Environmental, Health and Safety Guidelines in their finance activities in non-designated countries [152].

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.IFC GN6 precludes development in the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Sites [153], and Alliance for Zero Extinction Sites [154].

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 based on 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).

Case Study 3.12 Continued

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 additional conservation outcomes that can be achieved for the biodiversity values for which the critical habitat was designated.

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

If there are significant residual impacts after avoidance, minimization and restoration measures have taken place, net gain is achieved through the application of biodiversity offsets. 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.

In instances where a biodiversity offset is not part of the developer's mitigation strategy (i.e., there are no significant residual impacts), net gains may be obtained by supporting additional opportunities to conserve the critical habitat values in question. In these cases, qualitative evidence and expert opinion may be sufficient to validate a net gain.

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 and indirect impacts of a project. They also need to cover multiple seasons to properly understand how the baseline changes within and between years[37]. It is important to involve specific key stakeholders (such as biodiversity specialists, regulators and the project engineering team) in a project-specific baseline survey design. BOEM has published a series of guidelines for environmental, social, and physical surveys for offshore wind development, and these guidelines could help inform survey design in emerging markets [155].

Governments should ensure that developers conduct project-level baseline surveys to cover full calendar years, seasons and/or annual cycles. This is to properly understand ecological requirements, changes in species population and distribution, behavioral cycles, and key points in species life history. This may be, for example, a two-day survey period every month for two years. Comprehensive baseline surveys are likely to be required for the following biodiversity values:

- Species: Birds, bats, fish, marine mammals, and sea turtles; and
- Natural habitats, such as corals reefs, seagrass beds and mangrove forests.

There is a role for government to coordinate and assess acceptable cumulative impacts of multiple offshore wind projects in the same area. Developers are competitors and cannot access each other's data, therefore collaboration on cumulative impacts assessment is generally low, risking leading to lower quality cumulative impact studies.

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 can be perceived to outweigh the benefits [156]. To illustrate this point, Case Study 3.13 describes how the Cape Wind project in the US was ultimately abandoned due to public resistance [157] and goes on to discuss Vineyard Wind that has had a more positive permitting experience.

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

CASE STUDY 3.13

US Cape Wind and Vineyard Wind Projects

In 2017, a planned 420 MW wind farm in the US with 130 turbines was ultimately abandoned due to protracted resistance, including multiple legal challenges [158]. Cape Wind faced local resistance, supplemented by significant high-profile individuals who contributed at least US$1.5 million to campaigns opposing the development [159]. 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 as a result the site was selected by the developer with limited stakeholder engagement.

In 2021, the permitting process for Vineyard Wind 1, the US's first large-scale offshore wind farm was completed. Local stakeholders had been engaged and were supportive of this project [160]. 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 local opposition from halting the progression of an offshore wind farms. This is of particular importance for early projects where a local track record is not available to reassure stakeholders. The Federal Infrastructure Permitting Dashboard [161] is a good example of government ensuring good communication regarding permitting activities.

Good quality ESIA coupled with public consultation can help reduce local objections. Local stakeholder groups such as commercial or artisanal[38] 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 efficacy 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 3.10. 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.

FIGURE 3.10: 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 be able to provide rational input. 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 3.14, for early lessons from the UK on consultee resources during permitting that are also likely to be relevant in emerging offshore wind markets.

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

CASE STUDY 3.14

UK Permitting: The Value of Well-Resourced Consultees

There were substantial permitting delays in the early years of the offshore wind industry in the UK. In part, this was driven by a combination of a limited evidence base from which to draw conclusions about the impacts associated with offshore wind and statutory consultees who lacked the resources required to engage with such complex infrastructure projects. These challenges came to a head in relation to the Docking Shoal offshore wind farm. Following a consultation process that ran for over three years and cost £10 million (US$13 million), planning consent for the project was refused. This was due to uncertainty surrounding project impacts meaning the Secretary of State was unable to conclude that there would be no adverse effect on the integrity of the North Norfolk Coast Special Protection Area.

In response, The Crown Estate funded six roles in statutory consultees, and supported two collaborative research programs, Collaborative Offshore Wind in the Environment (COWRIE) and Strategic Ornithological Support Services (SOSS). In combination, these actions helped to ensure consultees were better resourced to engage fully with the assessment process, and enabled stakeholders from across the industry work collaboratively to address key evidence gaps. This helped to ensure future assessments could be completed in an efficient and timely manner.

Where communities are impacted by multiple projects, the government can play a key role in coordinating the interactions between the projects and the communities. This can avoid confusion and poor communication between the communities and multiple counterparts.

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 [162]. See section 3.10.

Key success factors

Related to permitting for offshore wind, governments should:

A. Establish a transparent, robust, and flexible permitting process with regulated review and approval periods.

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 and coordination areas with cumulative impacts.

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. Like other renewable energy projects, revenue certainty can be increased by long-term offtake agreements[39] (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[40]. In these countries, the revenue support mechanisms have been designed to give project developers[41] a known and guaranteed power purchase price, typically for a period of 15 to 20 years. Developers value the revenue stabilization[42] provided by governments, as it helps them manage revenue risk and hence reduce LCOE.

Many emerging markets do not have liberalized wholesale electricity markets, and the state-owned utility may be the sole offtaker, typically under long term contracts, for power projects developed and owned by IPPs. In such cases, there is no wholesale electricity market to sell into. Depending on the market structure, the generators would enter into a long-term PPA with the offtaker at an agreed tariff or the tariff would be simply set by regulation. 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. The scale of offshore wind can represent a significant offtake obligation in certain markets with material contingent liabilities. It is critical to consider the long-term financial viability of the sector and the offtaker(s).

39 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.

40 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.

41 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.

42 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 need to provide a revenue support mechanism. Early projects typically have higher costs than later projects and may be more expensive than the prevailing power price in that market. Enabling the project will therefore require a form of subsidy or passing the cost to end consumers, or a combination of both. As previously discussed in section 2.3, the LCOE of offshore wind can be expected to fall with subsequent projects, reducing the need for subsidy support or additional cost to consumers. Setting the level support and which support mechanism to use are key policy decisions by governments tackling the tradeoff between stimulating attractiveness for a new market and potential financial burden on the government and/or consumers [163].

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 if 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. Examples of their use in a range of markets are provided in Figure 3.11. These include:

- **Feed-in tariff (FIT):** Here, a government sets a fixed power price and pays for electricity produced over a proportion 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.[43] 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)[44] 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:** Like FIT, but the government pays a premium above the wholesale price. Denmark used this for "open door" projects (see [129]). 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.

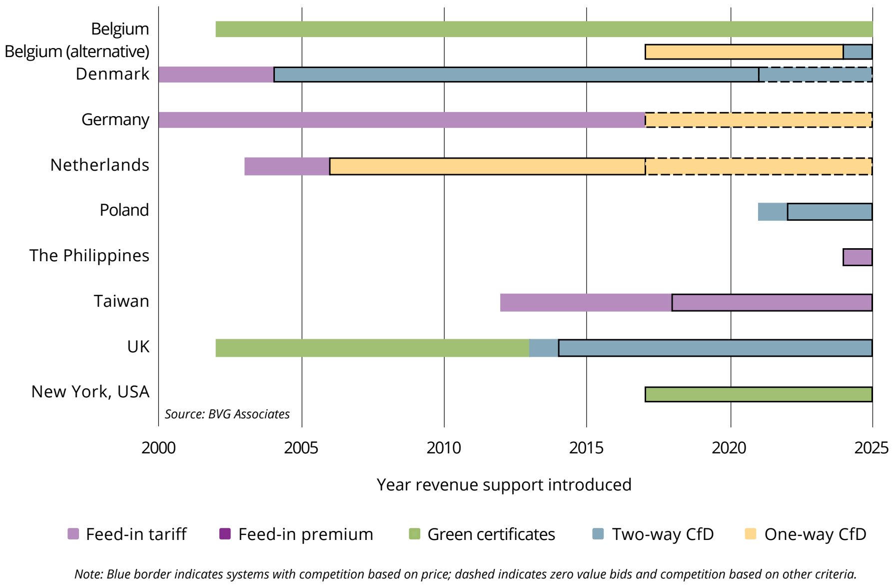
43 The tariff is set in law (which therefore carries a risk of change in legislation, as seen for onshore renewables in Spain in 2014).

44 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 [377]

- **Contract for Difference (CfD):**[45] 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 a proportion of a project's life. There are two main forms:
  - In a one-way CfD, when the wholesale price is lower than the CfD strike price, the contract provides a top-up payment to the developer, equal to the difference between the wholesale electricity price and 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.

FIGURE 3.11: EVOLUTION OF FINANCIAL REVENUE SUPPORT SYSTEMS IN A RANGE OF MARKETS



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

Fiscal support

Incentives can also be in the form of fiscal (typically tax) incentives [164]. 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.

45 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.

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 precedent for governments providing financial incentives, such as tax benefits, for power projects; similar incentives could be applied for the offshore wind industry.

Processes for awarding offtake agreements

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

- At what stage of project development will agreements be awarded and by what mechanism?
- What kind of offtake agreement or revenue support mechanism will be offered?
- 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 seabed rights, combined into a single award, after the government has carried out early-stage project development work (the one-competition model).
- Separately, after seabed rights 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 seabed rights in section 3.4.

The reliability of competitive price discovery increases, and risk premiums decrease the later in the project development cycle that auctions happen. This is because project developers have increased certainty about the designs, suppliers and costs for their projects the further through project development they are. Historically in the UK, for example, revenue support auctions have taken place after permitting and grid connection agreements are in place, and just before financial close.

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. If this is not done, 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 3.15.

CASE STUDY 3.15

UK's Final Investment Decision Enabling for Renewables Program

The UK Government used the Final Investment Decision Enabling for Renewables (FIDER) program in 2013 [165] 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) [166].

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. Bilateral agreements do not provide transparency or enable a competitive market and hence are unlikely to offer long-term value to electricity consumers. 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 therefore more likely to be challenged by future political administrations. It also risks impacting competition and sending negative 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. Given visibility of large-scale competitive markets in established countries, industry has demonstrated its ability 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 3.16.

CASE STUDY 3.16

Impact of Auctions

The introduction of competitive auctions has proven to be an effective method of driving down the cost of offshore wind. In 2011 the levelized cost of energy (LCOE) of an offshore wind project was typically in the range of US$230 / MWh, and the industry had reached a crossroads. There was a large pipeline of projects in Germany and the UK, but governments were cautious about supporting these projects at an elevated cost.

The first country to introduce auctions was the UK where, 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 and 170 / MWh (at 2012 prices). Subsequent auctions in Denmark, Germany, the Netherlands, and the UK 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 had been a key part of this change, but it has also been driven by the need for project developers 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 just their projects into revenue support 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.

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.

Careful auction design, including minimum requirements from bidders, and market engagement are essential to minimizing those risks.

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 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 [167].

Concession (2010–2014) A competition selected four state-owned enterprises (SOE) to deliver China's first large scale-projects. The projects were delayed for seven years because the bidding prices were too low [168]. 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.

Case Study 3.17 Continued

Market competition (2019–onward) Provinces ran auctions for offshore wind tariffs, with the first auction in 2019 resulting in LCOEs of CNY 0.62/kWh (US$96/MWh) [169]. Tariff price accounted for 40 percent of the total evaluation score, with evaluation also including bidders' financial strength and project technical plans [170].

Despite this 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.

Experience in established markets has shown that industry consultation during the design of auctions helps to create acceptable conditions and maximizes the chance of a successful outcome. Case Study 3.18 provides some examples of failed auctions, where unattractive auction conditions led to no bids being submitted.

CASE STUDY 3.18

Examples of failed auctions

Denmark 2024 auction

In its 2024 offshore wind auction, Denmark offered three sites with capacity totaling 3x1 GW, with the option to overbuild each site by another 1 GW, making a total potential capacity of 6 GW. The auction failed to attract any bids. This was widely attributed to two key factors [171]:

The 'negative bidding' auction structure employed in Demark, which does not provide a revenue guarantee like the CfD systems employed in many other markets, but seeks upfront payment from developers to secure sites, who then sell electricity on the wholesale market.

Uncertainty over future wholesale revenues, driven by the fact that a large proportion of Denmark's electricity needs (55 percent) are already met by wind power. This led to fears of surplus wind power driving down prices and impacting project revenues.

Case Study 3.18 Continued

UK Allocation Round 5

The UK's Allocation Round 5 (AR5) in 2023 ended without any offshore wind bids. Following the perceived success of AR4 in 2022, which delivered 7 GW capacity at a record low strike price of £37.35 (US$46) / MWh,[a] the UK Government set the ceiling price (maximum allowable bid price) for offshore wind in AR5 at £44 (US$55) / MWh.

In the light of increased costs because of increases in commodity prices and the cost of finance, developers declined to bid below such a low ceiling price [172].

In AR6 in 2024, the UK Government responded by raising the ceiling price to £73 (US$93) / MWh. The auction was successful, with 3.4 GW new capacity secured at a strike price of £58.87 (US$75) / MWh [173].

Türkiye's First Offshore Wind Auction

Türkiye's first offshore wind auction in 2018 identified specific sites, but set a relatively low ceiling price, included high 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. Subsequently, the Government of Türkiye has worked with the World Bank Group to establish an offshore wind roadmap published in 2024, giving clarity on the industry's long-term development and building on the lessons learned from the first auction [174].

a. UK CfD prices are quoted throughout in £2012.

It is beneficial to gather relevant data inputs to inform price expectations and auction parameters, prior to launching an auction process. Bid prices are driven by underlying project LCOE, and collection of headline data on the factors impacting LCOE, in consultation with industry and with the support of expert independent consultants, can help governments understand whether auctions are likely to meet their price expectations and help inform auction parameters to avoid failed auctions. Key underlying data which influence bid prices include:

- Mean wind speed
- Water depth
- Metocean conditions
- Seabed conditions
- Project size

- Technology type (size of turbines, fixed or floating foundations
- Distance from project site to ports and grid connection
- Weighted average cost of capital (WACC)
- Commodity prices, especially steel
- Grid connection and other regulatory costs.

Value Factors

Consideration of priorities other than price can be built into revenue support competitions to help meet wider policy objectives. These auction conditions are referred to as 'value factors', though they are also commonly referred to as 'non price factors' or 'non-price criteria'. Value factors can encompass a wide range of non-price priorities, such as:

- Impact on biodiversity
- Impact on circular economy
- (Cyber)security
- Developer record
- Financial capability
- Carbon emissions
- Project Deliverability
- Social impact
- Supply chain development
- System integration.

Value factors are typically implemented in one of two ways: As scored criteria, weighted alongside bid price, to select auction winners, or as pass/fail prequalification criteria which permit access to an auction.

An increasing number of Governments around the world are seeking to implement value factors in revenue support competitions. The EU is currently proposing, via the Net Zero Industry Act, that Member States should include value factors in offtake auction from 2026. See Case Study 3.19.

CASE STUDY 3.19

The European Union's Net Zero Industry Act

The EU's Net Zero Industry Act (NZIA) plans to introduce mandatory value factors for renewable energy auctions in EU Member States, starting from January 2026. The NZIA was adopted in May 2024 and entered into force in June 2024. The act contains provision for two types of value factor assessment:

Prequalification Criteria: The NZIA requires Member States include three categories of prequalification criteria:

- Cybersecurity
- Responsible business conduct
- Ability to deliver

Award Criteria: Each award criterion must have a minimum weight of 5 percent, with a combined weight between 15 and 30 percent of the overall assessment, with the remainder being based on bid price. The NZIA requires inclusion of three criteria at this stage:

- Resilience (reducing dependency on imports of net-zero technologies from third countries)
- Sustainability
- Other factors (for a Member State to determine).
- Alternatively, resilience and sustainability may be assessed at the prequalification stage.
- The EU's Wind Power Action Plan, announced by the European Commission in October 2023, calls upon Member States to include "objective, transparent and non-discriminatory qualitative criteria" in their auctions.

Case Study 3.19 Continued

In the Netherlands' 2024 auction, two 2 GW sites were auctioned, Ijmuiden Ver Alpha and Beta. For the Alpha site, value criteria focused on biodiversity protection. For the beta site, the focus was on system integration.

SSE, the winner of the Alpha site, committed to design it as a "living laboratory" — more than 75 percent of the wind turbines in the wind farm will have artificial reefs for mussels and other maritime organisms. Vattenfall and CIP, winners of the beta auction have committed to building a 1 GW electrolyzer facility in Rotterdam which will run on renewable electricity from the project [175].

In a two-competition model, value factors may be implemented at the seabed rights stage as well as the offtake auction stage. If using value factors to encourage supply chain development, this may be a more appropriate stage at which to include such criteria, as it allows sufficient time for commitments to be delivered before project construction commences [176].

Generally, scored value criteria at the award stage are challenging to implement effectively, and are likely to increase costs. By diluting price competition within auctions, the use of value factors is likely to increase cost of energy to the consumer. Determining an appropriate way to balance diverse and unrelated priorities within a shared auction frameworks, and appropriate ways to score them on a shared scale, is challenging, adds complexity and can fail to deliver desired outcomes where requirements are not robustly specified. This practice is still in its infancy and there is limited evidence of best practice. Instead, implementing a stage-gate approach to ensure minimum standards are met to qualify for an auction represents a safer way to ensure wider government priorities are reflected without compromising price competition.

If using value criteria, they should be as measurable, objective and quantifiable as possible to enhance transparency and reduce risk of litigation [177]**.** The number of different non-price criteria employed should be minimized, enhancing predictability of outcomes and therefore attractiveness to investors. Qualitative criteria which are open to subjective interpretation should be avoided where possible. These criteria reduce transparency of auction outcomes, increase risk of legal challenge and may in some cases increase the risk of corruption or of awarding points to a bid for certain content which do not significantly help deliver the desired objectives.

Local content requirements in auctions are not recommended. Mandating use of local suppliers which are not cost competitive or increase risk increases LCOE and ultimately consumer energy prices. Local content requirements also add complexity to frameworks, disincentivizing investment. In addition, they risk inviting challenge based on WTO rules or another international trade agreements, which typically prohibit favoring domestic firms in public procurements. Legal challenges can introduce significant delay and uncertainty to deployment timelines, as seen in Taiwan, China. Clarity of long-term pipeline and well understood delivery frameworks coupled with market-based investment incentives such as in the UK and Denmark have typically been more effective in driving supply chain development. See Case Study 2.9 for more information on different countries approaches to local content, and Case Study 4.2 on successful supply chain investment initiatives.

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 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 Energy Security and Net Zero (DESNZ) 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.
Use of value factors	In the 2022 Hollandse Kust West auction, two sites were auctioned. In each case, 50 percent of scoring was allocated to value factors. At the first site, value factors focused on biodiversity impacts, and at the second, on grid integration.	For the CfD AR7 auction in 2025, the UK Government introduced the Clean Industry Bonus (CIB). The CIB requires developers to make qualifying investments up to a certain minimum level per GW in supply chain and infrastructure development to participate in the auction. They may also make applications for additional support beyond the required minimum level [258].	NYSERDA assesses bids against a range of criteria, which include price (70 percent), local economic benefit (20 percent) and project viability (10 percent).

	1. Netherlands	2. United Kingdom	3. US (New York)
Pros[46]	Direct competition between developers for same project. Consideration of value factors allows for focus on wider government priorities.	Competition between projects, now for access to price stabilization at minimal cost to the Government. Simple, quantitative approach to value factors provides clarity to industry and may drive supply chain investment.	Clear understanding of evaluation criteria between cost local economic benefit and viability.
Cons[47]	No price competition when zero-subsidy bids. No price stabilization to reduce developer revenue risk when zero-subsidy bids. High proportion of scoring based on value factors risks adding cost to energy bill payers, as well as adding complexity to the bidding process.	Developers carry significant spend and risk up to award.	Potential disconnect between states and federal Government.
Further information	See [133] [178], [179]	See [180] [181]	See [182] [183]

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, China 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 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, but needs to recognize the large scale of offshore wind projects.

Case Study 3.20 provides guiding principles to consider when formulating an offshore wind PPA.

46 See also pros and cons of one- and two-competition models in Figure 3.3

47 See also pros and cons of one- and two-competition models in Figure 3.3

Offtake agreements are typically structured to provide some flexibility in start date, recognizing 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 World Bank Group [184]. An existing offshore wind power purchase agreement [185] can provide a useful starting point for consideration.

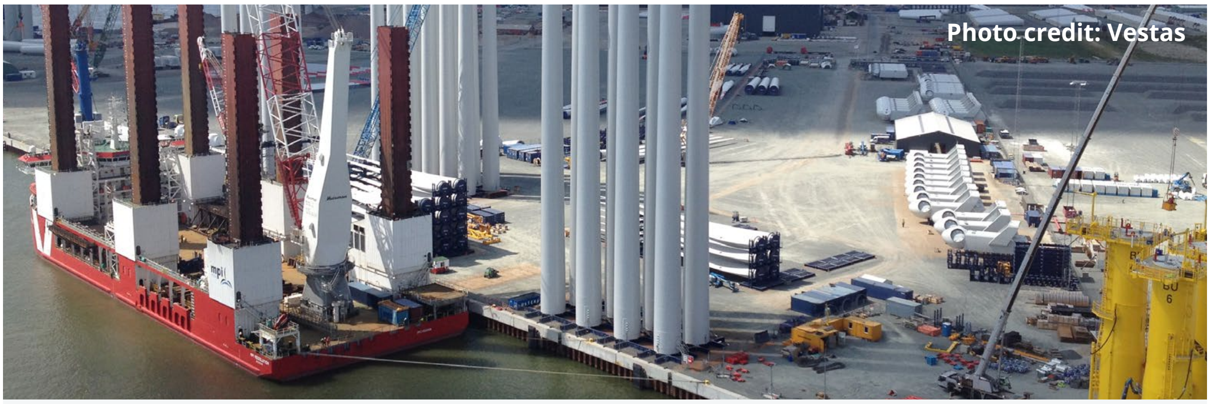


Photo credit: Vestas

CASE STUDY 3.20

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 [184]):

1. **Dispatch risk**. Offtake should be on a take and pay basis whereby the seller is paid for all energy produced; if 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. Often, the tariff will be indexed against an economy-wide consumer price index, to keep pace with inflation. It may also be indexed against specific commodity prices, especially steel. Fluctuations in the price of steel can significantly impact project costs, and this risk can impact bankability if not accounted for in the PPA structure.
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.

Case Study 3.20 Continued

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. If 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

Some projects in established markets with high mean wind speeds have sold 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, China). The uptake of CPPAs can introduce new challenges; for example, the UK 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. As the need for revenue support reduces, governments should look at introducing rules to allow corporate PPAs as an option for project developers.

As more confidence has been gained in the offshore wind industry, CPPAs have been set up in advance of project construction. For example, Ørsted 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 2026 [186]. In Taiwan, China, CIP signed a PPA for 500 MW capacity from its Fengmiao 1 project, which will enter commercial operation in 2027 [187]. 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 such large volumes of energy and cannot enter into CPPAs for tenures 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 and a liquid wholesale power market as last resort.

In emerging markets, projects without some form of subsidy or revenue support are unlikely to be attractive to investors. This is because of challenges in identifying suitable corporate offtakers, compounded by the additional risk associated with operating in less established markets.

As the global energy transition continues, offshore wind may be used in the production of green hydrogen[48] and other products such as green ammonia for use in industry and transportation. This is an area in commercial development around the world [188]. First green hydrogen projects primarily target existing demand and do not necessarily source energy from offshore wind. As the green hydrogen market grows and trading and transport of molecules progresses, opportunities for offshore wind-based green hydrogen production from resource rich areas of the globe could open up. Markets see opportunities arising for hydrogen export from offshore wind or for new supply chain development. [189] [190] [191] [192].

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.

D. Avoid qualitative and overly complex value factor assessments at the award stage. Use a prequalification stage to assess project deliverability.

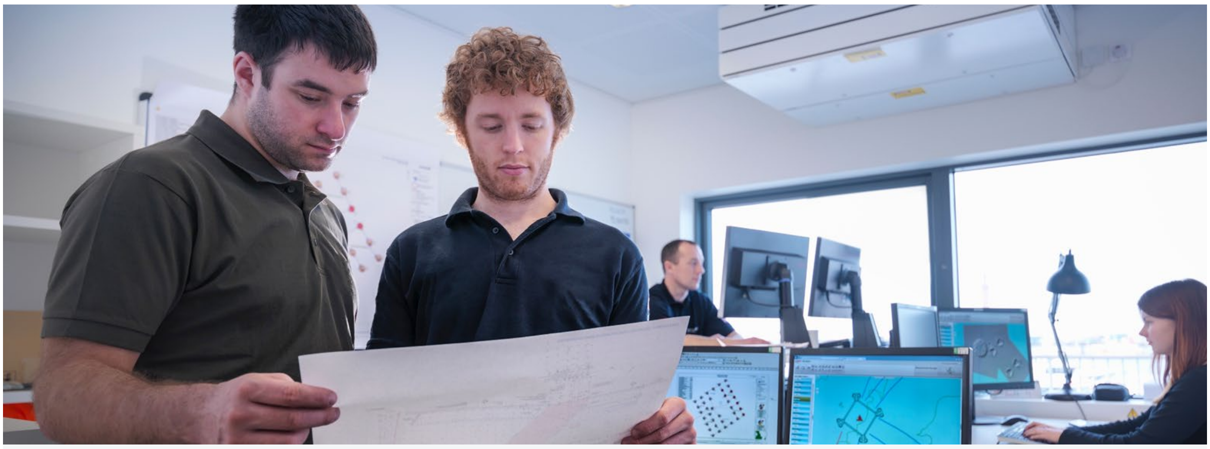
Suggested reading materials are found in Appendix A and full references found in Appendix B.

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

3.7 EXPORT SYSTEM AND GRID CONNECTION

Securing a timely grid connection is emerging as one of the largest barriers to offshore wind in established markets such as the UK, Netherlands and Germany. Transmission network reinforcement and long lead times for specialist high voltage equipment have resulted in grid connection delays and capacity restrictions across Europe. This has resulted in governments performing holistic review of the approaches to grid connections ensuring speed of connection and value for money for consumers — see Case Study 3.21.

Many emerging markets face their own grid challenges even before the introduction of offshore wind. Careful planning and implementation of grid strengthening and expansion plans are key to supporting a new offshore wind market.



CASE STUDY 3.21

Holistic Network Design and GB Grid Connection Reform in UK

Holistic Network Design (HND) in the UK, carried out by the network operator (NESO), aims to provide a coordinated approach to onshore and offshore grid design to meet offshore wind connection targets and achieve net zero ambitions by 2050 [193] [194]. 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 [195].

The integrated approach provides material cost benefits. It is however expected to take longer to implement than a less integrated approach, potentially delaying future projects. Careful planning is therefore required [196].

In January 2025 the NESO announced a temporary halt on accepting new transmission connection applications, as it aims to address a backlog of grid applications and move to a more streamlined process [197]. This is in preparation for carrying out holistic grid connection reform to fundamentally alter the way grid connections are allocated, shifting from a “first-come, first-served” to a “first-ready, first needed” approach [198].

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 [199], were expensive and affected industry confidence. Export systems can have the longest lead time of any element of an offshore wind project.

Developers require a clear, bankable, framework to apply for a grid connection underpinned by credible grid strengthening or expansion plans and processes where required. It can take many years before a grid 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 seabed rights or permitting process.

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.

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. 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. 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 [60], can help mitigate this risk. In emerging markets, those protections can represent material contingent liabilities for the system operator which can be handled by robust grid planning and commitment to delivery.

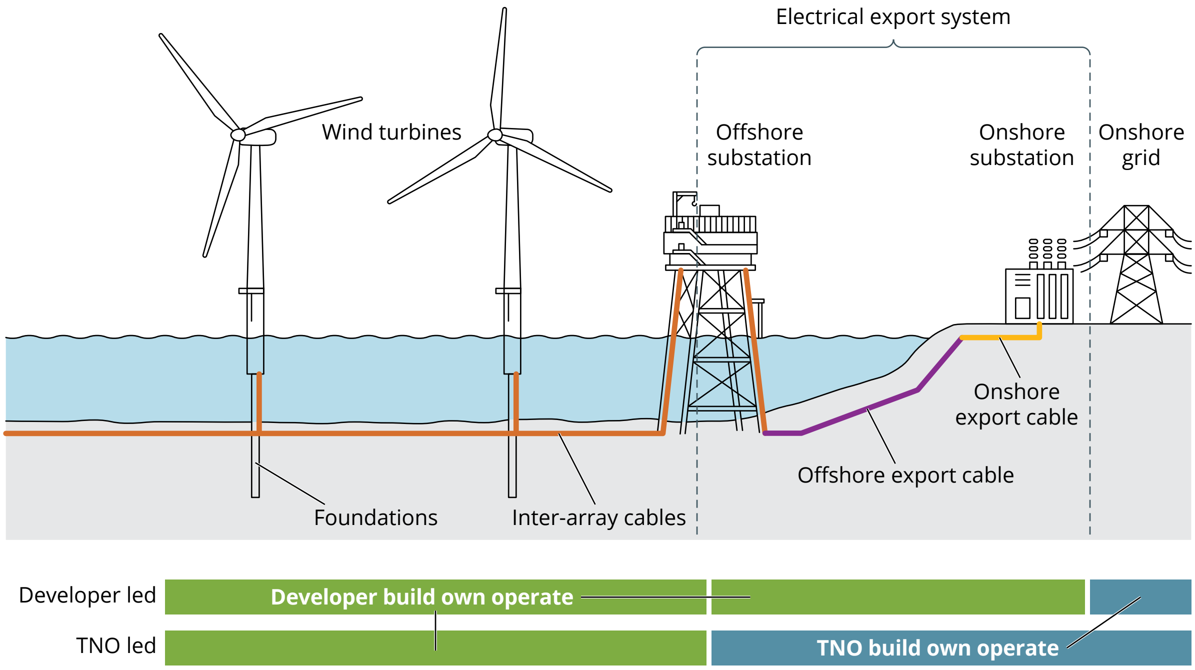
Grid connection costs should be reflective of transmission network upgrade requirements, and use of system charges[49] need to be based on a clear framework [200]**.** The allocation of costs for connecting a new offshore wind farm to the transmission network can generally follow one of two philosophies, "deep" or "shallow" charging:

- In a deep charging regime, the connecting party covers the costs for local upgrading of the transmission network. 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 transmission network, such as an extension to an onshore substation at the grid connection point. In this case, transmission network 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 transmission network reinforcement that other users subsequently benefit from. This approach can result in additional costs for the first developers to connect to the network.

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

FIGURE 3.12: OVERVIEW OF OFFSHORE WIND FARM EXPORT SYSTEM AND BUILD/OPERATE APPROACHES



Source: Adapted from [201].

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 [202] and in Germany [203] 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 3.9). The EU developed harmonized grid connection standards in 2016 to support all forms of generators [204].

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 3.22. 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 3.22

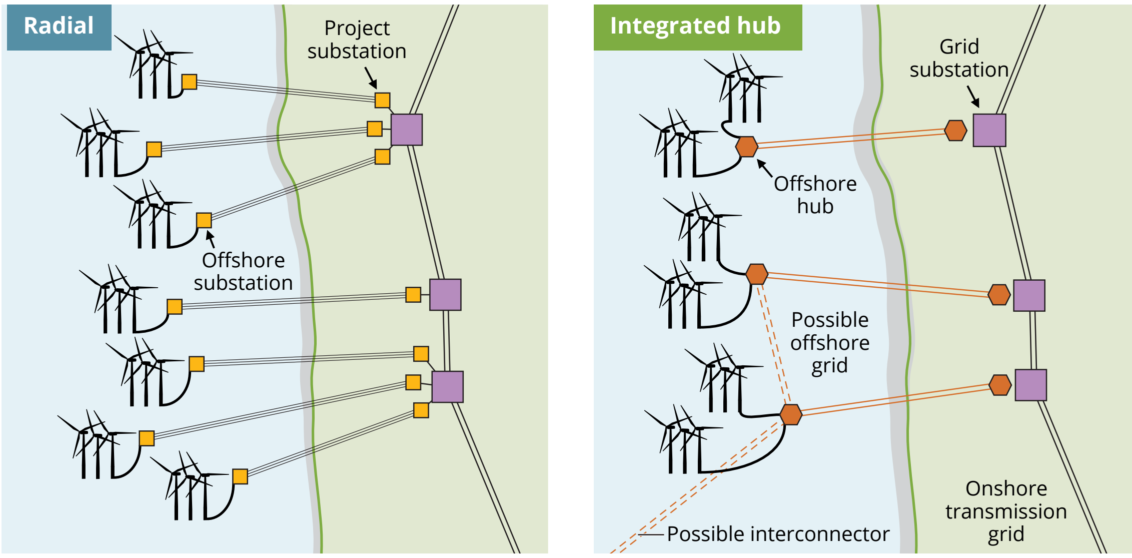
Grid Curtailment Compensation Mechanism in Germany

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 [205]. 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.

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 3.13). Different export system options were compared by the New Jersey Board of Public Utilities when considering which approach to favor [206]. Benefits can be achieved through coordinated grid design, as were implemented in the UK. Each country will have different arrangements and evolving needs, so such reviews are important in enabling best-value solutions.

FIGURE 3.13: 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.

Governments can play an important role in ensuring a timely and cost-effective offshore export system to connect into the 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 3.12. 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.

Export system ownership and operation can lie either with the wind farm owner, 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 3.23 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 3.23

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. The Government, however, 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 [207].

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) [208].

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 [209].

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 [60].

To create the cost savings, a standardized alternating current (AC) substation with a capacity of 700 MW was 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.

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 3.24) In some countries it may require adjustment of the legal or regulatory framework.

CASE STUDY 3.24

Rentel Offshore Export System Approach

In Belgium, for 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) were 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 [210].

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 prevent 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 are 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, China, the US

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, if involved at all, they tend to partner with experienced parties.

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 3.23 and Case Study 3.24 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.

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 activities, informed by available environmental and social baseline data. This can reduce the risk of delays at the project permitting and development stages.

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 World Bank Group (WBG) provides a series of general and sector specific environmental, health, and safety (EHS) Guidelines [211]. 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. They are supported by most developers, work in a collaborative and inclusive approach and aim at supporting new markets. These organizations have an extensive portfolio of technical experience and data that emerging markets can draw on. Globally recognized safety and technical standards [212], along with best practice guidelines [213], have been developed for offshore wind. Many leading offshore wind companies are members of the GWO, which issues training standards and accredits training providers. An example of one of its accredited providers is the Taiwan International Windpower Training Corporation [214], 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 developed with strong health and safety frameworks have been shown to outperform on delivery and economic success.

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, China, 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 3.25). A similar partnership has developed between local governance in New Jersey and the GWO [215].

CASE STUDY 3.25

Taiwan, China—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 [216]. 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, China. This encouraged leading developers, such as Ørsted to implement the highest quality, health, safety and environment (QHSE) standards on site for construction of its Changhua 1 & 2a wind farms [217].

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 [200] (see Case Study 3.26).

CASE STUDY 3.26

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 [218]. 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 [219].

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 [220] 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.

Alignment with international standards in emerging facilitates participation of established suppliers and support from international lenders. Ensuring that projects can access a wide range of international suppliers, use proven designs and operate within a regulatory context they already understand can help reduce LCOE. A bespoke domestic regime is likely to deter investment by developers and suppliers who are already geared towards meeting established international standards. An emerging market benefits from deployment of equipment from experienced wind turbine and other suppliers that may be new to that market. Governments should consider that local standards may restrict the participation of such suppliers.

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[50] [221], EN[51] [222], the International Organization for Standardization (ISO) [223], and other internationally recognized standards for design and manufacturing. Specifying these standards, rather than introducing onerous local national standards, can avoid additional costs and extended delivery times for parts. Governments can harmonize between relevant international and national standards where relevant. This was carried out in 2014 by the British Standards Institute (BSI) for offshore renewables [224].

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 certificated 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.

50 DIN: Deutsches Institut für Normung — or German Institute for Standardisation.

51 EN: Europäische Norm — or European Norm. Usually referred to as European Standards.

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 [225].

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.

3.10 COMMUNITY BENEFIT

It is fair for communities located near offshore wind farms and associated onshore transmission assets to receive proportionate economic benefit. Community benefit can also help governments and developers deliver wider socioeconomic and environmental priorities, increase support among local communities, help projects secure a social license to operate and in turn long term and provide stable political consensus which helps drive investment.

Types and purpose of community benefit measures

Community benefit can take various forms. This includes:

- A community benefit fund, through which a financial contribution is made by the asset owner to the local community. Such a fund is usually managed by a local authority or community trust and used to fund local projects beneficial to the community.
- Revenue sharing, under which, the distribution of a fraction of the financial benefit of a project is managed, usually by a local, regional or national government, to allocate within communities.
- Royalty structures, under which payments are made by the asset owner to the owner of the land on which assets are located.

- Community ownership, which could include full or part ownership of the asset by a community organization, or part-ownership of the project by individuals within the community, through purchase of shares. Community ownership has typically been applied more successfully in smaller-scale, local, onshore renewables than for large-scale offshore wind projects. Most offshore wind projects represent multi-billion dollar investments, in which communities are likely to lack the financial capability to take a meaningful stake.

Generally, the aim of such measures is to:

- Redistribute the economic benefits of offshore wind deployment aligning with the socio-economic objectives of the government or community.
- Mitigate the (real or perceived) negative impacts of offshore wind deployment, such as disruption from construction activity, visual impact of onshore or nearshore assets, or impacts on other sectors such as fisheries and tourism.
- Increase public support for offshore wind deployment by giving communities, either at a national, regional, or local level, a sense of ownership of the assets and sharing in the benefits.

Impact of community benefit measures

All mechanisms for delivering community benefit effectively redistribute benefit rather than create new benefit. All the mechanisms discussed above represent an additional levy on renewables deployment, which will have the effect of raising project LCOEs and ultimately consumer prices [226].

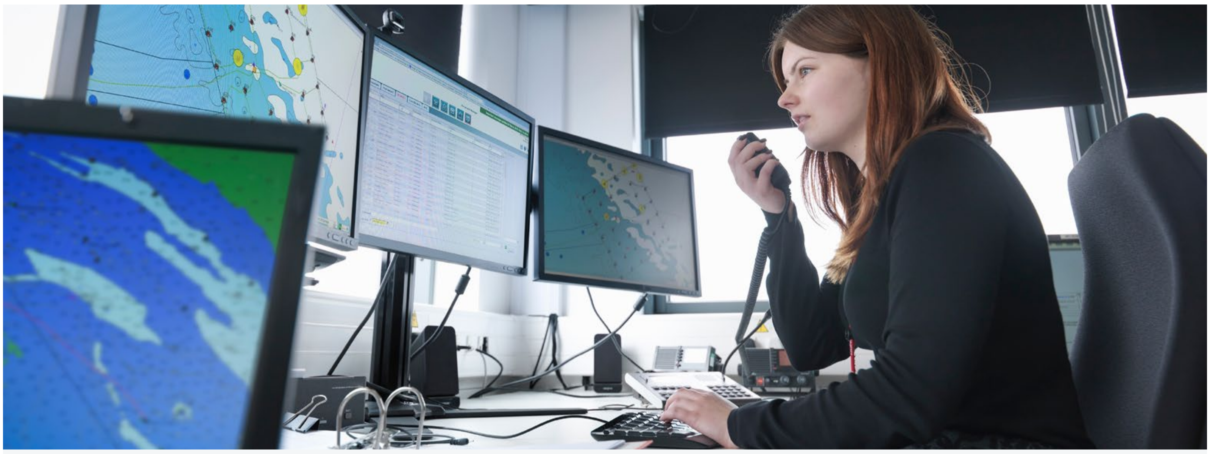
Community benefit schemes have value in directing economic benefits to communities most affected by offshore wind projects. Experience from other markets shows that ambitious ORE deployment can meet with significant public opposition when action is not taken to ensure communities close to projects feel the benefits.

A wide range of benefits can be delivered to communities via community benefit measures. Community benefits should be tailored to the needs of local communities and government's wider strategic objectives to ensure the desired benefits are achieved. These typically include:

- Skills and livelihood support;
- Public services and infrastructure;
- Environmental stewardship;
- Share of project proceeds, under community ownership models.

The 'right' level of community benefit contribution from offshore wind projects may depend on the nature of the project and its local impacts, but predictability of required contributions is key to delivering desired benefits while creating the right environment to attract investment. Where community benefit measures are required, but vaguely specified, this creates uncertainty for project developers and hence decreases attractiveness of investment.

Community benefits should be tailored to the realities of the energy market as well as the realities of the locations where offshore wind projects are sited. Delivering community benefits is only one of the many tools to foster strong company-community relationships. The provision of community benefits must be implemented alongside other strategies, including responsible management of project impacts and high standards of stakeholder engagement by the project and its contractors [227]. WBG has issued best practice guidance for implementation of community benefit measures in its report on the strategic value of community benefits in offshore wind, see Case Study 3.27.



CASE STUDY 3.27

The Strategic Value of Community Benefits in Offshore Wind Development

WBG's 2025 Strategic Value of Community Benefits in Offshore Wind Development report highlights the growing importance for offshore wind proponents to build strong relationships with host communities and secure a social license to operate [227]. The report provides insights into designing effective community benefit programs, drawing from more than 30 case studies from 18 different energy markets worldwide. It identifies five building blocks considered essential to the development and delivery of successful community benefit initiatives for offshore wind projects:

- Transparent communication and trust building;
- Strategy tailored to the local context;
- Phased engagement approach;
- Appropriate resources and expertise;
- Collaborations and partnerships.

There is a growing focus on how offshore wind can contribute to coastal community regeneration. Best practice and examples of practical implementation are available [228] [229].

Key success factors

Related to community benefit measures for offshore wind, governments should:

A. Ensure that communities most affected by projects receive the most benefit, to build public support and reinforce projects social license to operate.

B. Consider carefully the community benefit interventions which are most appropriate to the local context, and which align with wider government priorities, to ensure the right benefits are delivered.

C. Ensure that any community benefit requirements embedded in delivery frameworks deliver clarity in terms of expected contributions.

D. Allow flexibility within high level community benefit requirements, to ensure that interventions can be tailored to the specific needs of individual communities.

E. Ensure that measures do not jeopardize the financial feasibility of the project.

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

CHAPTER FOUR: 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 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?
- How can transmission network upgrades be coordinated to facilitate the connection of offshore wind projects?
- Where will the financing for offshore wind projects and associated infrastructure come from?
- What are the differences in the financing needs for offshore wind in comparison to other projects?
- How can capability of, and collaboration between relevant bodies be enhanced to derisk delivery?
- How can the expertise of international partners be harnessed?

As outlined in Figure 4.1, 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.

Beyond the topics covered in sections 4.2 to 4.6, 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, economic, and political developments.
- Managing industry-wide risks.
- Encouraging collaboration and innovation to solve local issues at a national level.

FIGURE 4.1 KEY ENABLERS UNDERPINNING OFFSHORE WIND 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.

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.

4.2 Supply Chain

The frameworks discussed in chapter 3 provide the regulations and processes to give offshore wind developers a clear project development pathway.

4.5 Financing

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

4.3 Ports

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

4.6 Collaboration, Capability and Partnerships

The development of a successful offshore wind industry takes a collaborative approach over many years. A generic map of typical stakeholders is shown in Figure 4.

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.[52] This section links closely with supply chain policy discussed in section 2.4, which also gives an introduction to the nature of the offshore wind supply chain and potential for localization.

Clarity of strategy, ambition and frameworks is often more important for driving investment in supply chain capacity than driving investment in projects. The business case for major investments in manufacturing and port facilities is rarely made on a single project. Rather, potential investors typically seek markets with robust project pipelines stretching over many years, and with a record of delivery and bankable routes to market before committing to significant capital investments. Initial projects alone are unlikely to trigger such investments, and are likely to rely on established facilities.

There has been a significant geographical diversification in the profile of the offshore wind supply chain. Cost increases resulting from increased interest rates and commodity prices, coupled with slower than hoped policy progress in many markets, have however led to lower than expected market volumes in established European markets which has resulted in profitability challenges. This is exemplified by Siemens Gamesa Renewable Energy and Vestas's 2022 and 2023 profit warnings [230], and GE Vernova's November 2024 decision to pause new offshore wind turbine orders [231]. These challenges have not been limited to turbine suppliers, and have led to underinvestment in supply chain capacity needed to meet long term global deployment ambitions [232].

52 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.

While a consolidation has taken place in Europe, there has been an increasing diversification and geographic spread of the supply chain. Over time many supply chain players have moved some or all their production to low-cost countries [232].

Despite growing geographical spread, emerging bottlenecks in global supply chain capacity represent a risk to further growth of the industry and meeting governments' deployment ambitions. See Case Study 4.1.

CASE STUDY 4.1

GWEC's Mission critical: Building the global wind energy supply chain for a 1.5°C world report [232]

In December 2023, GWEC released a report which outlined the current state of the global supply chain in the context of macro, geopolitical and economic outlooks impacting the supply chain. The report identified key emerging bottlenecks in the global offshore wind supply chain:

- **Component manufacturing capacity:** Challenges are particularly high in North America and Europe where manufacturing capacities for iron castings, gearboxes, converters and generators are low and hence projects are reliant upon imports.
- **Nacelle assembly:** Capacity is under pressure in all markets except China. This activity is particularly reliant upon attractive financial outlooks for wind turbine suppliers if critical investments are to be made into future assembly plants.
- **Subsea cable:** The rapid growth of offshore wind technologies increased demand for subsea cables that connect wind farms to the transmission network. This could become a bottleneck in the rollout of offshore wind as demand for new capacity rises quickly.
- **Ports:** Additional port capacity is required in all regions except China. GWEC estimates US$18 billion of investment in ports will be required to bring the current global pipeline of announced offshore wind projects online.

It has since published a similar report focused on the APAC region. [233]

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 these investments hard to justify, especially in markets that are new to them. Different countries have different fiscal and financial mechanisms to support such investments including:

- Targeted competitions, whether for capital support [234] or research and development (R&D) support [235].
- Tax incentives specifically for offshore wind [236] 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. 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) [237]. Specifically, in relation to offshore wind, this has been observed at the Port of Esbjerg in Denmark, and Humber and Teesworks in the UK (see Case Study 4.2).

CASE STUDY 4.2

Support for Industrial Clusters

Denmark—Esbjerg Port

The Danish Energy Innovation Cluster was established in 2016 to support industrial cluster development and has since worked with Esbjerg Municipality and industry association Wind Denmark to support a network of businesses which can benefit from synergies and shared clients [238]. The companies at the Port of Esbjerg represent a large part of the supply chain for the offshore wind industry. The port has already been involved in over 50 offshore wind farms [239].

UK—Humber and Teesworks

In 2020 and 2021 the UK Government introduced several initiatives to encourage port development to support offshore wind and industrial clusters. The Offshore Wind Manufacturing Investment Support (OWMIS) scheme [240] has supported the creation of industrial clusters through a £20 million (US$28 million) investment in the Teesworks port development. Following this investment, SeAH Wind announced it would open a new monopile manufacturing plant [241], suggesting that this approach helps attract international companies to support the offshore wind market.

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 through 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 [242] [243] [243] [244] [245].

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 the 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, a flagship education program has been mainly industry funded, as a result of the last government-industry "deal" [35]. 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 [246] 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 [247] [248]. National and regional membership organizations with wider energy interests often have a high focus on sharing opportunities in offshore wind [249] [250]. Energy 'share fairs', as pioneered in the oil and gas sector, can also play a role [251].

CASE STUDY 4.3

Industry-led Education and Support Programs

The Offshore Wind Growth Partnership (OWGP) was established as part of the UK's Government-industry sector deal in 2019. The OWGP is an industry-funded body that provides grant funding and business support to UK companies to help improve the competitiveness of the UK's offshore wind supply chain. It runs different business transformation programs to support companies at different stages of their involvement with the industry. For example:

- **Wind Export Support Toolkit (WEST):** A low-intensity, one-to-one intervention providing specialist consultancy advice to companies exploring opportunities within the sector.
- **Fit 4 Offshore Renewables: (F4OR):** A medium intensity intervention providing guidance to companies that are going through the process of bidding for work in the sector, focused on enabling companies to establish the right credentials to bid.

Case Study 4.3 Continued

- **Sharing in Growth (SG):** A high intensity one-to-one program that helps already established companies grow within the offshore wind sector.

Between 2019 and 2024 the OWGP supported 264 companies, providing £17 (US$21) million in funding support and £4.7 ($US5.9) million of business transformation activities. These interventions have created 1500 new jobs in the sector and led to combined £294 ($US370) million of growth in the turnover of supported companies [252].

Industry support activities

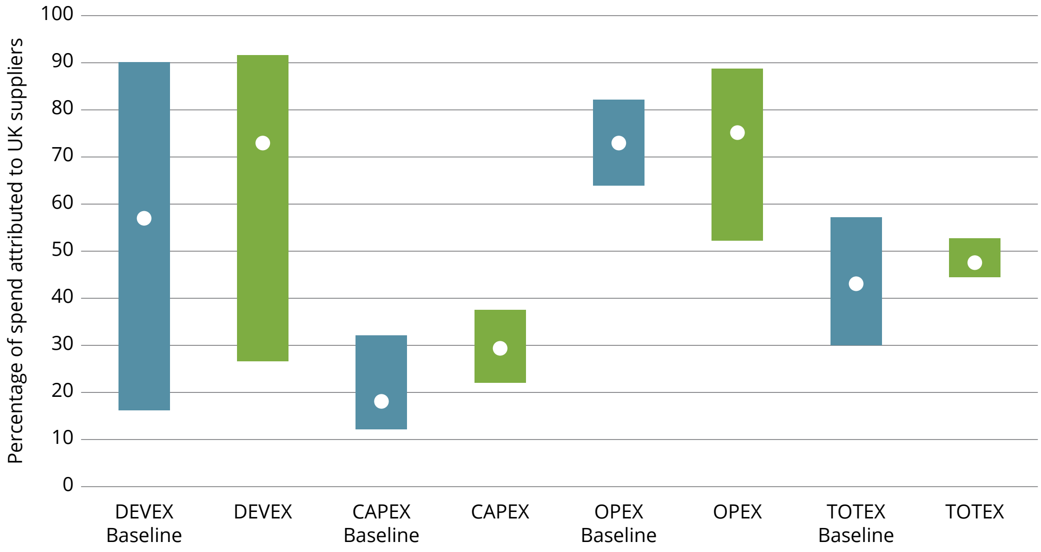
Supply chain databases play a useful role, if well delivered. It is helpful for organizations seeking to grow the supply chain and for purchasers in emerging markets to understand the capability of current and potential future suppliers. Several national and regional wind and wider energy trade bodies have created such databases [253]. A well delivered database is up to date, has verified, accurate information and does not solely 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 package to key offshore wind players by submitting corporate information demonstrating that they are a viable option. Based on this, purchasers draw up a short list of bidders for supply packages.

Measuring and reporting local content helps enable meaningful dialogue about local economic benefits. In dialogue, it is helpful to have robust definitions so that all parties are clear about the basis of government targets and reports by industry. The Taiwan, China 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 [255]. See also Case Study 4.4. Japan [61] and Poland [256] have followed similar processes to UK.

Figure 4.2 shows output of industry analysis of increased local content after measurement was introduced.

FIGURE 4.2: INDUSTRY REPORT ON INCREASED UK CONTENT OF UK OFFSHORE WIND FARMS AGAINST EARLIER BASELINE.



Source data: RenewableUK [257]

CASE STUDY 4.4

UK Content Methodology, Supply Chain Plans

To enable clear communication about local supply, the UK Government and industry worked together to establish the UK Content Methodology [255] that was first used in 2015 to document UK content on offshore wind projects. Systematic aggregate reports on local content using the methodology have been published [257] [258].

To drive focus on innovation, skills, and competitive local supply, in 2016 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 were published [259] [260].

Case Study 4.4 Continued

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. The commitments of the preferred developers form the basis of the lease option agreement [140].

In the 2025, supply chain plans for offshore wind projects were discontinued and replaced with the Clean Industry Bonus (CIB). The CIB is discussed in more detail in Table 3.4

Aside from technical standards, standardization of contracting practices can help increase efficiency and transparency within the supply chain and derisk project delivery. Offshore-wind specific contracting standards are yet to be widely established. Many contracts currently rely on terms imported from the oil and gas industry, which are not well suited to the specific challenges of offshore wind. These include International Federation of Consulting Engineers (FIDIC) [261], Leading Oil and Gas Industry Competitiveness (LOGIC) [262], and new engineering contract (NEC) [263]. Remedying this was a key recommendation of the UK offshore wind champion's 2023 independent report [264]. Efforts to standardize offshore wind contract terms are underway, led by industry organizations such as the International Marine Contractor's association and the World Forum Offshore Wind via the "FAIR" contracting principles initiative [265]. This is an industry-lead activity, which governments should be aware of and encourage, without the need for direct intervention.

An important ongoing focus for government should be enabling 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 seek to minimize LCOE.

Geography and standards play a role in determining developers' supplier selection. Due to the impact of transport costs and logistics risk for some components and services, geographical proximity of established supply chain plays a role in key procurement decisions. It is advisable to develop an understanding of key established suppliers within the region to assist in understanding where potential complementary capabilities, bottlenecks and opportunities for localization exist. Applicable product standards also play a role in supplier selection, and the compliance or otherwise of regional suppliers with specific standards should be considered in selecting a standards regime. See also section 3.9.

Forward visibility of a robust project pipeline, coupled with clear and predictable regulatory frameworks, and, where appropriate, economic incentives to drive investment, are the most effective measures to support development of a competitive local supply chain. Regulatory measures to mandate local content can often disincentivize investment and invite legal challenge, as seen in Taiwan, China (see Case Study 2.9). Tariff protections raise costs, increasing LCOE and hence the cost to consumers. They may also be ineffective in driving long-term benefit as export opportunities are likely to be limited for industries requiring tariff protections to be competitive, especially if other countries impose retaliatory tariffs.

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 Ireland [70], Humber, UK [266], New York [267], Virginia [268], and the US more generally [269]. Once needs are defined, governments and industry regularly work together to help develop skills [270] [271]. Sometimes this has been linked to retraining as part of the energy transition from fossil fuels to renewable energy.

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 [272]. 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) [273], 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 [274].

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.

Workers from related industries often have skills that can be quickly adapted to suit offshore wind. Analysis by Global Wind Energy Council (GWEC) showed that more than 0.5 million new wind power technicians will be needed between 2024 and 2028 thanks to industry expansion [69]. 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 [275]. 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 [276].

Encouraging sharing of project data and generation statistics in the public domain. Good examples of this are the Danish wind turbine register [277], which is maintained by the Danish Energy Agency and The Crown Estate’s annual offshore wind report [278]. 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 [279], *Schiffssicherheitsverordnung* in Germany [280], and "closed ports" in Japan [281], 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 [282] [58]. Support can be provided through a combination of grants, loans, or incubation programs, which are either general or specific to offshore wind [235], with a range of funding options available (public, partly, or fully industry funded) [283]. Some countries have established publicly funded research and technology organizations (RTOs) with a high focus on wind [284] [285] [286] [287]. RTOs help local and international collaboration and focus on key areas of innovation, as well as publicizing support opportunities [288].

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 [289], blade bearings at Fraunhofer IWES [290], blades at ORE Catapult [291], and complete turbines at the Østerild Test Center of the Technical University of Denmark [292]. 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 4.5 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 4.5

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, 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 [293].

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 [294], SusWind [295], and ZEBRA (Zero Waste Blade Research) [296] 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.

Technology innovation in the areas of digital, artificial intelligence (AI), and autonomous inspections all support LCOE reduction in offshore wind. Advanced control systems and the integration of machine learning and AI into wind farm design and wind farm and individual turbine control systems enables better performance, reliability and lifetime. Improvements in O&M through the use of drones, autonomous vessels and subsea vehicles not only lowers LCOE but also improves safety for operations like blade, foundation and cable inspection and even some repairs.

As floating offshore wind is much less mature, there remains much room for innovation and LCOE reduction. In the early years of fixed offshore wind, there was a great deal of learning about the degree to which cost reduction could be driven by innovation and economies of scale (see section 2.3). There is likely to be a similar journey for floating offshore wind over the next decade, notably through innovation in areas including industrialization of hull manufacturing, improvements to mooring, anchoring and dynamic cabling systems and the development of new installation, operation and maintenance methods [59]. For example, the introduction of up-tower cranes is likely to have a significant influence on the cost and lost revenue incurred during major component replacement — see Case Study 4.6.

CASE STUDY 4.6

Offshore major component replacement to reduce floating offshore wind LCOE [297]

Offshore major component replacement (MCR) is a major challenge for floating offshore wind turbines.

For fixed offshore wind turbines, a jack-up vessel can be used to remove and replace the component using processes similar to those used during installation. However, for floating wind there is much more relative movement between the hook of a floating crane and the nacelle.

One approach is to disconnect the turbine, tow it to port and perform the component exchange there. This was done to replace a generator on a wind turbine at Kincardine offshore wind farm with a duration from disconnection to reconnection of more than 50 days.

Innovation led to the development of technologies that permit the O&M provider to perform MCR offshore. For example, in the summer of 2024, a generator was exchanged on another turbine at Kincardine offshore wind farm with mobilization and operations taking fewer than 30 days. The reduction in cost and downtime both serve to significantly reduce LCOE of floating offshore wind.

Downtime can be further reduced by using up tower cranes to replace generators. In a large project, if a replacement complete floating wind turbine was available to swap in, this could reduce downtime even more.

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. Significant storage areas for components close to the quayside are necessary. 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 4.3.

TABLE 4.1: PORTS FOR FIXED OFFSHORE WIND — TYPICAL ATTRIBUTES FOR A 1 GW FIXED FOUNDATION WIND FARM

	Construction		Operations and maintenance (O&M)	
	Manufacturing	Marshalling/assembly	Crew transfer vessels	Service operation vessels
Description	Components such as turbine nacelles, blades, towers, foundations, 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[53]	9–12 m below LAT	3–4 m below LAT	7–8 m below LAT

53 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.

	Construction		Operations and maintenance (O&M)	
	Manufacturing	Marshalling/assembly	Crew transfer vessels	Service operation vessels
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.

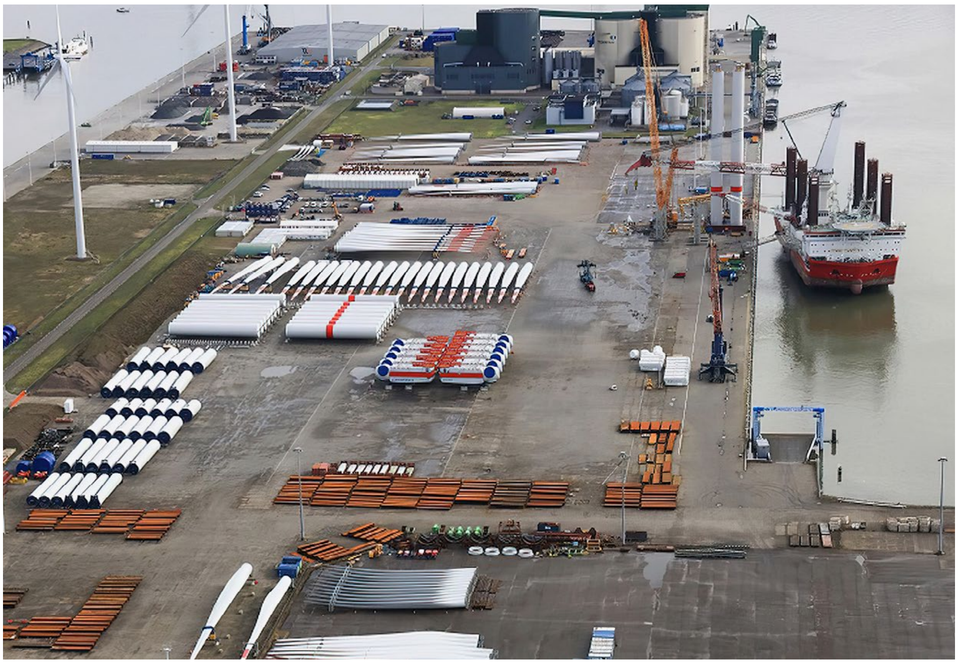
Other important attributes for the offshore wind industry include:

- Quay length (500 m will accommodate up to two mid-sized jack-up installation vessels),
- Quayside bearing capacity (20–30 metric tons/m^2 are required for load-out to adjacent vessels with storage areas needing a capacity of at least 10 metric tons/m^2),
- 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.

Based on 2020 Data with Allowance for Next Generation Turbine Technology[54] [298][55]

FIGURE 4.3: COMPONENTS FOR AN OFFSHORE WIND FARM AT EEMSHAVEN PORT



Source: Koos Boertjens / WindEurope [299]

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

55 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.

The challenges associated with manufacturing, marshalling and support services for offshore wind should not be underestimated. The requirements placed upon ports extends beyond the major components in Table 4.1 and multiple ports will be required for the manufacture and marshalling of a range of other components (including lifting equipment, templates & tooling, e.g. subsea array and export cables and associated balance of plant, anchors, mooring chains, quayside facilities) and support services (tugs, vessel refit and repair) associated with an offshore wind farm. Ideally, these ports will be clustered together to avoid a widely distributed, transport-sensitive supply chain. Most existing ports generally have limited port space, inadequate quay infrastructure, and insufficient heavy lift capabilities to be useful for offshore wind installation works. Engaging with stakeholders to identify investment opportunities and address these challenges is important. Coordinated efforts between public and private sectors to develop a sustainable and efficient offshore wind industry (see case study 4.5). For example, in 2025, the Scottish Government announced GBP 500 million investment programme to catalyze further private investments into supply chain and infrastructure upgrades for offshore wind [300].

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 [301], 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 foundations are likely to need quayside water depths of 14 to 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 [302], the Celtic Sea [128], and in the waters of France [303] and Spain [304].

The upgrades to ports to provide the necessary quayside space, quayside water depths, load bearing capacities and cranage for floating offshore wind are typically greater than for fixed offshore wind. These upgrades are mainly required to accommodate the large, heavy foundations and assembly of turbines on to foundations, and retrospectively strengthening quayside space is often a significant challenge. Typically, there is also a requirement for wet storage areas for foundations pending- and post integration with turbines; this requires sheltered water, navigation management around the area and considerable logistics planning. In the UK, one study estimated costs up to £500 ($US620) million for a major upgrade [264]. Costs depend on the nature of the upgrades required and local labor, material and construction costs. Upgraded facilities may have multiple uses.

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 multiple 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 on making any necessary port upgrades in good time (see Case Study 4.7). 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 4.7

New Jersey Wind Port

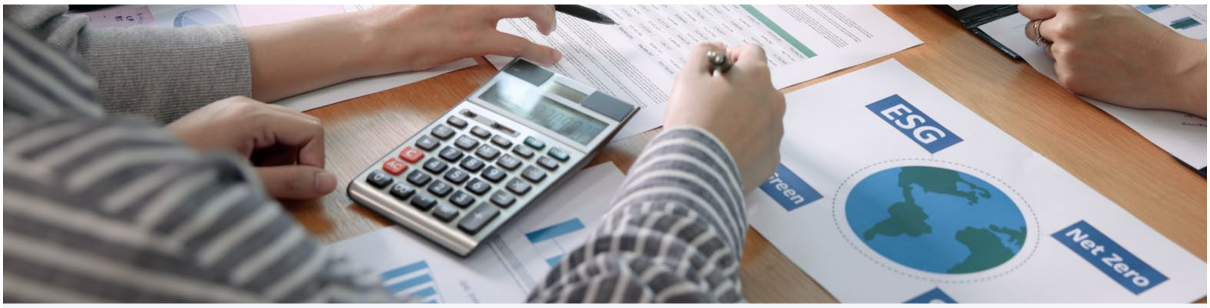
The New Jersey Wind Port is a purpose-built 80+ hectare component manufacturing and marshalling port. The port plan has been developed to deliver against an expected pipeline of future projects, with 7.5 GW of offshore wind in New Jersey by 2035 and further projects along the US east coast.

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 [305].

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 [298], the US [306], South Korea [307] and Viet Nam [308] have published port infrastructure studies. Feasibility studies for new-build ports or expansions should take account of all relevant environmental, social and technical factors. 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 projects, particularly in markets with water over 70 m in depth, which is most suited for floating wind.

To enable decisions to invest, port owners need confidence they will secure return on investment. This can take the form of financial commitment from customers such as wind farm developers, or grant funding, or a combination of the two, ideally coupled with a strong, visible pipeline of upcoming projects. A clear, credible roadmap like that provided by the Crown Estate for the Celtic Sea helps provide ports with confidence to invest in the necessary upgrades but is not enough by itself to enable port investment decisions. In areas where multiple projects are progressing at once, concepts akin to the Scottish Strategic Investment Model (see Case Study 4.5) can be used to increase the chance of investment.



CASE STUDY 4.8

Scottish Strategic Investment Model

The Scottish Strategic Investment Model (SIM) is a collaborative initiative designed to drive strategic investment in Scotland's offshore wind supply chain. Established by the Scottish Government and its agencies, the purpose is to accelerate investment and ensure the offshore wind supply chain can deliver on the ScotWind opportunity and beyond. The SIM has identified a potential pipeline of port infrastructure and supply chain projects with a total capital expenditure of around US$8.5 billion.

The SIM is intended to help build a shared view of investment need across the portfolio of ScotWind projects. By working across industry and the public sector, effort and potentially investment in infrastructure can be pooled and risks shared. The model focuses on building a sustainable offshore wind industry capable of meeting Scotland's net-zero targets, facilitating a just transition, and exporting Scottish capabilities globally. By pooling efforts and investments across industry and the public sector, the SIM is intended to help critical port infrastructure projects reach final investment decisions and subsequently support Scotland's offshore wind build-out.

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). To advance port developments, governments can follow one of two frameworks [237]:

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

A comparison of 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. Public investment in the port sector is, however, still common in many countries, including in Rotterdam and Esbjerg (see Case Study 4.8).

TABLE 4.2: PROS AND CONS OF PUBLICLY OWNED VS PRIVATELY OWNED PORTS

Publicly owned ports		Private ports	
Pros	Cons	Pros	Cons
Higher focus on economic growth generation. Control and coordination of national strategies and investments.	Political influence in decision-making. Lack of competition. Potential to have higher levels of inefficiencies in management and operations.	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 and typically require sufficient contracted activity to undertake investment which may mismatch the project timeline. Job creation and economic growth of a region not a priority. Financing can be more expensive for private organizations.

Governments have socioeconomic objectives in addition to objectives relating to direct financial returns. These objectives include job creation, and environmental and tax income. The allocation of government funds, however, is a complex decision with many factors. The investment payback for small port expansions is 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 [309], 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 their risk profile.
- Diversification to serve multiple industries rather than relying solely on offshore wind.

CASE STUDY 4.9

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 [310]. 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[56] (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 [311]. Ports traditionally form part of the national territory and contribute to government revenues through import duties. Many countries operate freeports [312], 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 chains and establish industrial clusters.

56 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.

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.

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, involving:

- Periodic network planning: Developing a 10-year (or more) forward-looking plan, updated annually, to ensure timely adjustments and comprehensive foresight in network capacity and constraints.
- Mapping existing constraints: Performing a thorough assessment of all incoming grid applications, planned network reinforcements, network changes, and shifts in generation (including the decommissioning of existing generation plants) alongside demand-side analysis to identify existing grid connection constraints.
- Identification of generation areas and demand centers: Determining areas with conditions suitable for offshore wind and population centers, to enable transmission network upgrades to facilitate the efficient flow of electricity from generation sites to demand centers.
- Scenario mapping, optioneering and analysis: Executing comprehensive studies to outline scenarios, identify potential system overloads (thermal and short circuit ratings), and establish the range of necessary reinforcements.

This maximizes the benefits of strategic network investments and reduces the risk of stranded transmission network assets if individual projects are not progressed. Grid connection availability can also help to inform spatial planning and the prioritization of different areas for seabed rights 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 [313]. 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 and hydrogen production can provide system flexibility that can help align renewable energy generation with demand [314].

Offshore wind power provides a more stable energy supply compared to other renewable sources. The International Energy Agency (IEA) has categorized offshore wind as "variable baseload" generation, reflecting its relatively high capacity factor (ranging from 40 to 60 percent) and consistent output. For instance, offshore wind output typically varies by about 20 percent from hour to hour, whereas solar photovoltaic (PV) power can fluctuate by up to 40 percent in the same timeframe [315].

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, government and project developers as part of long-term network planning. Typical approaches to export system design and ownership are discussed in section 3.7.

Grid support capabilities[57] 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 [316].

57 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 capital markets.

The offshore wind industry has a strong track record over the past 15 years, and financiers have grown increasingly comfortable with the technology. From 2010 to 2025, US$68 billion has been deployed to finance offshore wind in the UK and US$37 billion in Germany. Despite increasing costs and interest rates, a record 9 GW of new capacity in Europe was financed in 2023 [317], raising US$31 billion, including for the 2.85 GW Hornsea 3 offshore wind project.

China is the world's largest offshore wind market with an almost exclusively domestic participation and relying on domestic financing, often from public sources or using close relationships between large public companies and the banking sector. China's approach to offshore wind financing is often not directly replicable in other countries. Outside of China, offshore wind has primarily been developed in countries with stable macroeconomic environments with deep and experienced local banking and capital markets funded in hard currencies, more easily matched with the currency of project costs.

New offshore wind markets are opening up with more limited domestic banking and capital markets, and comparatively more volatile macroeconomic environments and currencies. Financing offshore wind in new markets will prove more challenging and will likely require different approaches. The experience of developers and financing institutions in financing projects in the context of those markets will play a critical role. Experienced international banks, development finance institutions[58] (DFIs), international financial institutions[59] (IFIs) (such as the International Finance Corporation), and export credit agencies[60] (ECAs) (such as Denmark's Eksport Kredit Fonden and Germany's Euler-Hermes) can help to raise the long-term financing needed, including to support specific supply chain contracts.

58 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. [417]

59 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 [375].

60 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 [376].

Financing structures

Offshore wind has historically been financed either using the internal financial resources of large companies (financing on balance sheet) or using non-recourse project financing which limits the impact of large investment on the developer's financial standing.

- **Financing on balance sheet** was necessary in the early days of offshore wind as the technology was being proven. In these cases, the developer uses its own resources to pay for development and construction expenses. These resources include internally generated cash flows, the company's equity and any borrowings the company can obtain from lenders, in the form of bank loans or bond issuance for instance. Given the large size of each project, the associated development risk and the growing pipeline of projects developers have been pursuing, many developers have felt the need to limit the impact of their offshore wind portfolio on their balance sheet. Some developers have, however, continued with this approach in certain markets as the quality of their balance sheet allows them to raise capital efficiently. For instance, Ørsted issued Green bonds in 2020 for a project in Taiwan, China [324]. [318]

Non-recourse project financing has enabled developers to limit their financial exposure to their equity contributions to the project (typically about 20 to 25 percent of project costs) and therefore significantly increase their investment capacity. 75 to 80 percent of the capital required for construction is typically raised from large banking debt syndicates, materially reducing the cost of capital. Banks only look to the project cash flows to cover their loan — without recourse to the financial resources of the project owner. This approach requires an intricate allocation of risks between the project, the lenders, the government and the other project counterparts (including offtakers, system operators, and contractors). All the risks embedded in the legal and regulatory framework, project agreements and the financing agreements are carefully analyzed and allocated for banks to gain comfort.

Although non-recourse project financing has been used for most construction of offshore wind, the development phase remains equity funded by the developers. The greater use of non-recourse project financing has demonstrated the degree of maturity and confidence built by the industry and financiers and allowed the industry to reduce the cost of capital and, in turn, the LCOE. New markets typically benefit from the lessons learned from previous markets on bankable risk allocation however every new market has specificities which will lead to differences in risk allocation.

In emerging markets, the local banking and capital markets are typically more limited than international markets, with lower liquidity, shorter tenor and higher cost. Local capital may not be sufficient to meet the funding requirements of building multiple GW of offshore wind. Accessing international capital is often a necessity to enable offshore wind, and in turn projects will need to offer a risk allocation acceptable to international lenders.

All policies, frameworks and delivery mechanisms relevant to offshore wind, ultimately are part of the risk allocation which enables or not a project to be project financed. As Governments design their policies, laws, regulations and procurement processes, it is essential to consider the requirements of the banks who will be looking to finance the construction of the projects. Those requirements are heavily focused on the appropriate risk allocation amongst the parties, but also include meeting international standards on environmental and social matters. Developers are acutely aware of the need to satisfy banks as they carry the financial risk of their project being rejected by the banks or being offered poor financing terms, leading to higher LCOE. It is important that governments engage with the industry and the banks to listen to their experience in project finance for offshore wind and collect feedback on the bankability of their policy, framework and delivery intentions.

Offshore wind projects are inherently more complex to develop and build, and larger in scale compared to other renewable technologies such as onshore wind and solar. As a result, banks tend to prefer financing the construction of projects led by experienced international developers with a strong track record and healthy balance sheet.

Government role in reducing investment risk

Governments need to consider how policy and framework decisions affect access to liquidity available to fund the projects while managing the risk exposure to the public sector. Policymakers should carefully consider how their decisions affect the ability to raise financing. This includes:

- Deliverability of the project, including project exposure to access to grid, port, vessels, supply chain and skilled workers which can be facilitated or restricted by policy decisions and government success in implementation of public policies and plans. Grid connection risk requires particular attention from the government as it is a critical consideration for financing. The ability to export power has a high impact on the project and its lenders who often require a compensation mechanism for lost revenues, such as payment for deemed energy generation.
- Visibility, predictability and stability of long term cash flows for the project, including project exposure to volatility in power prices and to interest rates, inflation or foreign exchange risks. In mature and emerging markets, the structure and terms of the revenue support mechanism and how it deals with each of these risks have a high impact on the project bankability. This varies significantly between countries and if a country changes its approach to revenue support. Governments should make sure to understand the lessons from international experience and to meaningfully engage with the industry to find the right trade-off between stimulating market appetite and increasing financial burden on the government or the consumers. For example, UK CfD Auction Round 5 received no offshore wind bids as the government did not sufficiently listen to industry feedback on price inflation (see Case Study 3.18). Poland's initial PLN-denominated CfD was met with some skepticism by the industry and faced serious financing challenges. Following industry engagement, the government revised its CfD structure and offered a choice of EUR-denomination or EUR-indexation which successfully attracted market participants and commercial banks to finance the construction.

- Alignment with international standards for project financing on key event-driven risks, including provisions for force majeure, change in law, arbitration & dispute resolution, lenders step-in rights and termination provisions. These more esoteric legal provisions are very important and can be elements of disagreement between government, industry and lenders with a binary outcome as parties can feel strongly about their position.

Although every market faces a similar set of risks associated with offshore wind, how acute each risk is, will vary widely between markets. In certain markets, access to grid connections will be the key risk which lenders will focus on, in other markets it will be foreign exchange or inflation. It is important for governments to use international experience and engagement with industry and lenders, to identify those risks that remain hurdles to investments. Governments have a range of tools available to address each risk and engagement allows them to identify how much a risk they should take on to enable investment without over-burdening themselves.

Mobilizing concessional finance

Concessional finance refers to any financial resource or instrument offered on terms that are more favorable than those usually available in a particular market. The use of this financing strategy could help overcome the initial cost premium when developing offshore wind in emerging markets as well as reducing costs for future projects. A 2023 report by the WBG Offshore Wind Development Program concluded that concessional climate financing can play a critical role in unlocking offshore wind in emerging markets and estimates that US$15 billion in concessional climate financing could catalyze offshore wind deployment of 10 GW across emerging market countries [319].

A blended approach of public and private concessional finance could enable LCOE reductions in emerging markets through the development and construction of pathfinder projects for instance, or funding ancillary infrastructure needed for offshore wind (transmission network or port upgrades, for instance). Major sources of concessional climate finance include the Climate Investment Funds (CIF), Global Environment Facility (GEF) and Green Climate Fund (GCF).

Role of public ownership

There are two key motivations for public ownership of offshore wind farms:

- Financial returns, and
- Strategic influence or control over the asset, which can be driven by a number of public policy considerations (including defense, environment and energy security).

In China, public ownership of offshore wind through State-Owned Enterprises (SOEs) is common. SOEs have renewable targets and actively participate in the offshore wind market. The public sector is closely involved in the success of the sector, including by providing significant financing and support.

Outside of China, offshore wind has mostly been developed by the private sector or by public entities with a private-sector approach. Certain large public or mixed-ownership utilities have pioneered the industry through R&D and development of the first projects. A number of these entities have become industry leaders with significant record in offshore wind. A key consideration is the differentiation these utilities make between their commercial operation and activities that may fall under their public service role. Offshore wind is considered by those utilities as a purely commercial activity where they compete and seek an acceptable risk-adjusted return. These utilities often have a high degree of technical competence which allowed them to become best-in-class in offshore wind, as well as taking on significant financial obligations and the ability to manage risk. Except for the industry pioneers in their early projects, these utilities have learned offshore wind through partnerships and joint ventures, working with experienced developers. This is a more practical approach to acquiring competence. In emerging markets, the public company's knowledge of the local context, regulations, permitting processes and political landscape can be a significant value-add for an international developer in partnership. The CIP / SK joint-venture on Jeonnam 1 in Korea is successful example of such public-private partnership.

Numerous sovereign wealth funds (e.g. Norges Bank), public pension funds (e.g. CPPIB of Canada) and public investment vehicles (e.g. UK's National Wealth Fund or France's CDC) have invested in offshore wind. These funds act as financial investors, bringing significant capital and discipline in governance, including credible independence from the state, and high competence investment management. These public investors mostly seek financial returns, seeing offshore wind as an attractive asset class within their portfolio.

In 2024, the Danish Energy Agency introduced a novel approach to public ownership by launching tenders for 6 GW of offshore wind with a requirement of 20 percent state ownership. Unfortunately, this tender received no bids. This new feature was one of the key elements for the failure of this tender. See Case Study 3.18 for more information.

In 2024, the Colombian Government initiated a seabed rights competition for offshore wind projects. A notable feature of the Colombian approach was that awarded bidders are required to enter into a shareholding agreement with a Colombian public or mixed-ownership company of the energy sector. This approach aimed to facilitate skill transfer on the development of offshore wind projects, promoting public ownership, oversight in the sector and aid regulatory processing [320].

It is much less common and more sensitive to consider public ownership for the purpose of strategic influence or control over the asset. From the perspective of the developers, this introduces a significant political and governance risk into the project. Structuring public ownership through the avenues described above preserves a distance between the project and the state which is often reassuring for investors and lenders.

Credit enhancement instruments

Governments should consider early engagement with credit enhancement providers to prepare for the financing of offshore wind. Financial sustainability of the power sector and sound budgeting for revenue support are 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. Such 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 the currency denomination of revenues and the currency of construction and financing cost is a common challenge in emerging markets. Given the size of offshore wind projects, this risk represents a large potential exposure. Neither procurers, offtakers, lenders or international investors are keen to be carrying this risk, which for many countries cannot be hedged over the long term in the required volume.

An offshore wind farm has two key phases of currency risk:

- From the revenue mechanism award date to construction: currencies can move against the project, making it more difficult for the project cash flows to underpin the capital raise required to pay the construction contracts, mostly denominated in hard currencies. This can create a gap in the financing plan, require additional equity or undermine project financial viability.
- Operational phase: fluctuation in currencies can undermine the project's ability to meet its debt repayment and pay expected returns to investors.

The risk allocation is determined by the currency denomination and/or indexation of the revenue support mechanism. Multiple mechanisms are available to allocate this risk:

- Price denomination and settlement in hard currency fully allocates the risk to the offtaker or party settling electricity payments.
- Price denomination and settlement in local currency fully allocates the risk to the project.
- Mixed currency price (with a portion in each currency) shares the risk between the counterparts.
- Price denomination in local currency with full or partial indexation to the hard currency allocates fully or partially the currency fluctuation risk to the offtaker but leaves the conversion and repatriation risk with the project.

The risk can be mitigated with the following approaches:

- Introducing local currency in the project costs by utilizing local supply chain.
- Where available, using short to medium term foreign exchange hedges for the period to construction payments.
- If possible, raising local currency capital from local banks and investors to reduce the mismatch between revenues and payments obligations during operation. ECAs and DFIs can also help provide local currency funding in certain markets.

Where a project faces a currency mismatch, the risk allocation and mitigation strategies are never perfect. It is important that government carefully considers this risk when designing the revenue support mechanism as it is a key feature of the project bankability and viability.

Inflation risk is a material consideration for developers. It can erode earnings over time, and is a particular risk in emerging markets with high inflation.

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 4.9. Poland initially faced a similar challenge and ultimately offered developers the choice of a EUR strike price CfD or a PLN strike price fully indexed to the EUR. This decision unlocked significant amount of EUR liquidity for Polish offshore wind [321]. Many emerging markets are likely to find less capacity and liquidity in their local banking and capital markets than in Europe or Taiwan, China.

CASE STUDY 4.10

Financing Offshore Wind in Taiwan, China

Taiwanese Changfang and Xidao offshore wind projects (collectively CFXD) provide valuable examples of challenges and efforts in raising local financing for offshore wind. They used 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 life insurers in Taiwan provided 7.5 percent of NT$30 billion (US$1.1 billion) equity [322].

Inflation considerations

Similar to foreign exchange risk, there are two main phases to inflation risk:

- From award to construction, as construction costs may escalate faster than anticipated and leave the project with a gap in the financing plan.
- From operation onwards, operating costs or expected nominal equity returns could be escalating faster than anticipated.

Policymakers have a few options:

- No indexation in the revenue support mechanism, which fully allocates the inflation risk to the project for both phases.
- Indexation from award to construction, which allocates the inflation risk during that phase to the offtaker and during operation to the project.
- Inflation indexation during operation, which allocates the inflation risk to construction to the project and during operation to the offtaker.
- Inflation indexation throughout, which fully allocates the risk to the offtaker.

Indexation can be full or partial depending on the understanding of the items which carry an inflationary risk and the proportion of those costs in the overall project costs for construction and operation.

Equity investors typically seek inflation-adjusted returns, therefore tend to require that the project returns are compensated for inflation. Lenders' compensation is usually not compensated for inflation (although some project bonds have been inflation-linked), but if project revenues are not indexed to inflation, lenders' repayment risk increases with inflation as debt repayment comes after the project operating costs are paid.

In certain mature markets, projects are able hedge inflation using certain indices, though this is not available in emerging markets. Delaying contracting could partially mitigate the risk but when the supply chain is in tension and lead times are long, projects are pushed to place orders early, which increases inflation risk.

Where a project faces both foreign exchange and Inflation risks, the question of indexation relates to the currencies in which the revenues will be denominated or indexed. The two risks are intrinsically linked. Emerging markets face both risks.

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 although geopolitical considerations around Taiwan have made this harder.

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 [323]. Industry and insurers experience is also providing better knowledge of certain events likelihood of occurrence and their associated financial impact which makes insurance markets adjust their offering over time, accepting certain risk but rejecting others or increasing premia.

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 developers and lenders and credit enhancement providers on key risk and bankability issues to understand the financing implications of policies choices.

C. Consider the financing implications of the terms and structure of the revenue stabilization mechanism, including on foreign exchange and inflation risks.

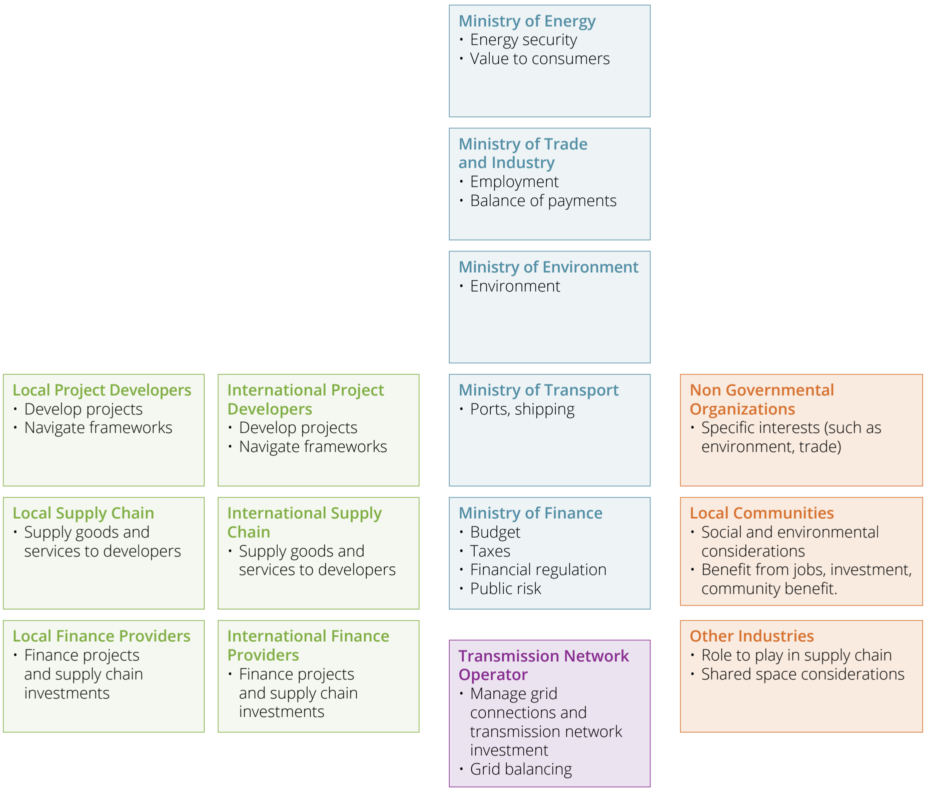
D. Create a regime and environment which gives investors access to insurance from the international insurance and reinsurance markets.

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

4.6 COLLABORATION, CAPABILITY AND PARTNERSHIPS

The development of a successful offshore wind industry takes a collaborative approach developed over the course of many years. A generic map of typical stakeholders is shown in Figure 4.4.

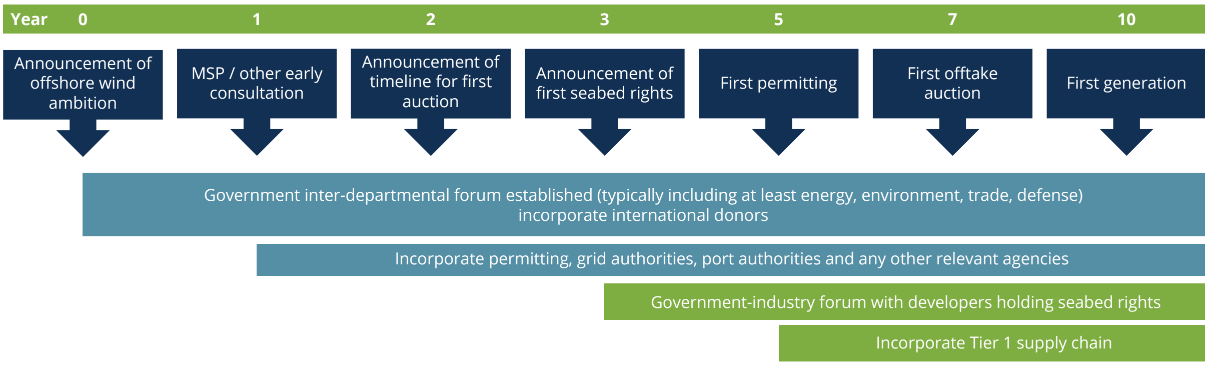
FIGURE 4.4: GENERIC MAP OF TYPICAL STAKEHOLDERS IN THE DEVELOPMENT OF A SUCCESSFUL OFFSHORE WIND INDUSTRY



Bodies that bring together government, international wind industry and local wind industry players have an important role to play in progressing delivery. Communication, collaboration and trust between parties is key to implementing change and addressing issues, for example as discussed in Case Study 2.2 and Case Study 3.3. Such bodies are best established involving project developers holding sea bed exclusivity awards, with major suppliers joining as the industry matures. Positive collaboration with industry based on alignment of strategy, policy and frameworks can be an important tool in building investor confidence and market efficiency.

Cross-government buy-in and coordination is often critical to successful market delivery. Typically, early stages of strategy and policy development are driven by the energy ministry, however later in the process collaboration is needed with other departments, especially at the marine spatial planning stage, where offshore wind developments can come into conflict with other users of the marine environment. Cross-government collaboration is most effective when policy impetus comes from the top of government, for example the president or Prime Minister's office, who can use their convening power to ensure all relevant government bodies are united behind the underlying strategy, and avoid delivery becoming mired in inter-departmental disagreements. Figure 4.5 shows a recommended timeline for establishment of cross government and industry-government collaboration groups. The Interministerial Commission for Marine Resources (CIRM) in Brazil is a good example of effective cross-government collaboration, as discussed in Case Study 4.10.

FIGURE 4.5 RECOMMENDED TIMELINE FOR ESTABLISHMENT OF CROSS GOVERNMENT AND INDUSTRY-GOVERNMENT COLLABORATION GROUPS



CASE STUDY4.11

The Interministerial Commission for Marine Resources, Brazil

The Interministerial Commission for Marine Resources (CIRM) is an interministerial group responsible for coordinating actions related to the National Policy for Marine Resource in Brazil. The CIRM is made up of and led by key government departments, including the Ministry of Mines and Energy, the Ministry of the Environment and Climate Change and the Brazilian Navy.

CIRM is responsible for the planning and execution of Brazil's Marine Spatial Plan, which forms part of the Continental Shelf Survey Plan. Together, these documents will guide and define use of marine space within the EEZ, including designating areas for offshore wind development [16].

The interministerial group has helped to build partnerships across government and industry to advance a clear marine spatial planning agenda. It has brought together various stakeholders to ensure a unified approach to managing offshore resources. This includes government departments, industry partners, environmental organizations, research institutions and local communities.

Within government and regulators, capacity building work is important to accelerate and derisk delivery. The resourcing and capability needs to develop and operate a robust delivery framework are significant, and staff members will require training to enhance their understanding of offshore wind industry dynamics and understanding of investor behavior.

International donors are playing an increasingly important role in capacity building and industry development in emerging markets. National governments from the UK, Denmark and the Netherlands as well as multilateral institutions such as the World Bank, the Asian Development Bank, the European Union and philanthropic foundations have supported countries around the world in pursuing their offshore wind goals. They have funded work from national roadmaps to capacity building in environmental research. It is likely that the donor landscape will continue to evolve over time.

To maximize the value of donor contributions, coordination is needed to define activities and desired outcomes well and to play to strengths and motivations. Different donors have different strengths and motivations, for example a government of a leading offshore wind market typically will be seeking to use its country's industry experience to create new opportunities for trade. Donors will both listen to government needs and suggest activities. There is a recognition in the donor community of overlaps and an openness to support coordination by national governments. Although coordination takes effort, the benefits are significant.

Key success factors

Related to collaboration, capability and partnerships, governments should:

A. Establish groups to bring together government and industry, and to coordinate activity across government departments.

B. Recognize the importance of building trust between government and industry, based on alignment of strategy, policy and frameworks.

C. Recognize the importance of capacity building within government to accelerate and derisk delivery.

D. Coordinate different donor organizations to ensure a joined up approach, and avoid duplication.

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

CHAPTER FIVE: NEXT STEPS

Photo credit: Ørsted

While this report aims to help government officials recognize the key 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 [324], and national offshore wind roadmaps published by WBG [6].

- The Global Wind Energy Council (GWEC) offers further support, including its offshore wind Market Readiness Assessment Toolkit [200], which shows the areas where government focus is most needed
- World Bank Group's Offshore Wind Development Program offers offshore wind technical resource maps [325], which show the potential for offshore wind for many 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 [326] 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 [327] provides a forum for state and non-state actors to have person-to-person exchanges on offshore wind.
- Key global offshore wind players, including those in the Global Offshore Wind Alliance (GOWA) and Ocean Energy Pathways (OEP), provide ongoing engagement and support.
- Independent wind industry and policy consulting firms can provide detailed support.

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 that offshore wind is a rapidly changing industry operating within a global energy transition.

APPENDICES

APPENDIX A: RECOMMENDED FURTHER READING

1. ENERGY STRATEGY

1.1 Offshore Wind as Part of an Energy Strategy

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

- DNV's Energy Transition Outlook [15].
- UK National Grid Future Energy Scenarios [1].
- The 2035 Report — a strategy for 90 percent clean electricity in the US by 2035 [328].
- UK Government 2050 Electricity System Analysis, planning for net zero emission by 2050 [329].
- The Solutions Project — a vision to achieve 100 percent renewable energy with modelling for nearly every country across the globe [330].
- Renewables 2024: Analysis and forecasts to 2030 [331].
- Infrastructure Outlook 2050 — a joint study by Gasunie and TenneT on integrated energy infrastructure in the Netherlands and Germany [332].

For relevant energy strategies, see:

- EU Strategy on Offshore Renewable Energy [333].
- Danish energy strategy to 2050 [2].
- Scottish Government's Energy Strategy [334].
- UK Government's Energy White Paper — Powering Our Net Zero Future [37].

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

- Guide to an Offshore Wind Farm by BVG Associates [145].

For overviews of floating offshore wind, see:

- Guide to a Floating Offshore Wind Farm by BVG Associates [335].

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

- A Crown Estate commissioned study for the UK [336].

For discussion on attractive investment, see:

- UN principles for responsible investment [23].
- WBG report on concessional finance [24].

2. POLICY

2.1 Introduction

For examples of visions for offshore wind, see:

- New York State's Offshore Wind Master Plan [26]; and New York State Energy Research and Development Authority's (NYSERDA) Master Plan studies web page [27] for the many supporting studies.
- Japan's Offshore Wind Industry Vision [29].

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 Deployment [337].

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 [30]. This led to 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 [255].

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 [32]. This led to a first Government-industry offshore wind "deal" in the UK.
- The Offshore Wind Cost Reduction Task Force's Report [33] for a report summarizing shared Government-industry commitment to delivering cost reduction in offshore wind.
- The UK Government's Offshore Wind Sector Deal [34] for information on UK's second Government-industry offshore wind "deal".
- Offshore Wind Growth Partnership website [35] for information on industry commitment after the UK's second Government-industry offshore wind "deal".
- Offshore Wind Industry Council web page [36].

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

- UK Government's Powering Our Net Zero Future [37].
- WindEurope's article on Poland adopting the historic Offshore Wind Act [39].

- For examples of long-term national visions and roadmaps, see:

World Bank Group's Roadmap for offshore wind in Vietnam [6].

- Subsequent World Bank Group national roadmaps for Azerbaijan [338], Brazil [16], Colombia [339], the Philippines [121], Romania [340], Sri Lanka [341] and Türkiye [174].

For an example of a national guide communicating policy, technologies and innovations, see

- The Dutch Offshore Wind Innovation Guide [60].

2.2 Volume and timescales

For examples of a volume target to 2040, see:

- An announcement on the German government's website [40].
- Japan's Offshore Wind Industry Vision [29].
- Poland's Energy Policy to 2040 on the Polish Government's website [41].

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

- The Transnational energy cooperation between North Sea countries [42].

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

- BVG Associates' Our energy, our future report for WindEurope [43].

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 [44].

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

- Ocean Panel's Ocean Solutions That Benefit People, Nature and the Economy [45].

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 [5].

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

2.3 Cost of energy

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 [30].
- The Crown Estate's Offshore Wind Cost Reduction Pathways Study [32].
- BVG Associates' Offshore wind cost reduction pathways report for detailed information on the technology-related cost of energy reduction [53].

- Cost Reduction Monitoring Framework by the Offshore Renewable Energy Catapult [54].
- Committee on Climate Change's Approaches to cost-reduction in offshore wind report [55].
- International Renewable Energy Agency's Innovation Outlook: Offshore Wind report for an exploration of the innovation landscape in offshore wind [56].
- The InnoEnergy Future renewable energy costs: offshore wind report for structured analysis of costs and cost reduction opportunities in offshore wind [57].
- UK Offshore Wind Industry Council Innovation focus on offshore wind [58].

For examples of government cost targets, see:

- In Japan: Japan Wind Power Association's 2nd Council Meeting Report [61].
- In UK: The Crown Estate's Offshore Wind Cost Reduction Pathways Study [32] and Offshore Wind Cost Reduction Task Force's Offshore Wind Cost Reduction Task Force Report [33].

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 [34].

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

- Recharge article: Taiwan's new policy can turn it into a major regional offshore wind hub [64].
- Statement from European Commission resolution of WTO dispute over Taiwan's offshore wind auctions [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 [6].

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

- IRENA's Renewable Energy Benefits: Leveraging Local Capacity for Offshore Wind [342].

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 [71].

For material on workforce and skills for offshore wind see:

- GWEC's Global Wind Workforce Outlook 2024 - 2028 [69].
- Skillnet Ireland's industry and workforce opportunities interactive guide [70].

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

- The UK's Industrial Strategy Offshore Wind Sector Deal [34].
- For best practices guidelines for gender diversity in talent recruitment, see:
- GWEC's Best practices [73].

2.5 Environmental and social sustainability

For a broad view of sustainability considerations, see:

- United Nations Sustainable Development Goals [104].
- World Resources Institute, High Level Panel for a Sustainable Ocean Economy website [106].
- The Kunming-Montreal Global Biodiversity Framework website [74]
- IUCN and World Bank Group discussion of nature-based solutions [83] [84] [85]

For details of The Crown Estate's work addressing knowledge gaps and sharing information see:

- Offshore Wind Evidence and Change Programme [38].

Marine Data Exchange [92].For early work on cumulative impact, see

- IUCN's Guidance on biodiversity cumulative impact assessment for wind and solar developments and associated infrastructure [80].

2.6 Stakeholder engagement

For guidance on good practice, see:

- IFC Performance Standard 1 [93].
- The International Association for Public Participation Core Values [94].
- The International Association for Public Participation Spectrum of Public Participation [95].

3. FRAMEWORKS

3.2 Organizing frameworks

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

- Danish Energy Agency web page [96].
- Dutch RVO web page [97].

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 [98].
- In Taiwan, China: Information on the Guanyin Offshore Wind Farm project [99].

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

- In Japan: Mitsubishi research Institute's article [61].
- In the UK: Offshore Wind Industry Council web page [36].
- In the Netherlands: Lessons from a Dutch community of practice [123].

For a tool to help assess the state of frameworks for offshore wind, see

- Market Readiness Assessment Toolkit [200].

3.3 Marine spatial planning

For further big-picture sustainability considerations, see:

- United Nations Sustainable Development Goals [104].
- 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 [105].
- World Resources Institute's High Level Panel for a Sustainable Ocean Economy [106].
- UN's Transformations for a Sustainable Ocean Economy [107].

For collaboration between countries and examples of MSP, see:

- European MSP Platform website [109].
- Offshore Coalition for Energy and Nature (OCEaN), Memorandum of Understanding [110].
- The Eight Baltic Sea Countries Ink Offshore Wind Pact [111].

For exaples of national offshore wind MSP, see:

- The Philippines Offshore Wind Spatial Planning Project: Final report [119].
- Viet Nam Offshore Wind Sectoral Planning [120].

For good practices on MSP, see:

- World Bank Group's SenMap guidance [115].
- UNESCO's website for much information about MSP [75].
- Consortium including UNESCO: Marine spatial planning: a Step-by-Step Approach [114].
- World Bank Environmental and Social Standards [116].
- Spatial planning for wind and solar developments and associated infrastructure [343].
- European Commission's Study on best practices in maritime spatial planning for offshore wind power [344]

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 [122] and Our energy, our future report [43].

For the legal basis for MSP, see:

- The United Nation's Law of the Sea [124].

3.4 Seabed rights

For examples of seabed rights frameworks developed in different countries, see:

- The Netherlands Enterprise Agency's website on Hollandse Kust (noord) Wind Farm Zone, Site V [133].
- The Crown Estate, Offshore Wind Leasing Round 4 web pages [134].
- BOEM's website for upcoming leases and roadmap to gain a lease [135].

For an export system leasing consideration, see:

- The Crown Estate, Export transmission cables for offshore renewable installations — Energy and Infrastructure Policies, Procedures and Guidelines [136].

For more information on BOEM and its processes for the US, see:

- The BOEM website offshore renewable energy activities overview page [137].
- BOEM National and Regional Guidelines for Renewable Energy Activities web page [138].

For good examples of communication about seabed rights, see:

- The Crown Estate, Offshore Wind Leasing Round 4 web pages [134].
- The Crown Estate Offshore Wind Leasing Round 4: Bidders Information Day — Morning Session [132].

For leasing frameworks and guidance developed in the UK:

- 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 [139].

See the Crown Estate's Marine Data Exchange for information on technical data sharing in offshore wind [92].

See G+ Global Offshore Wind Health & Safety Organisation for health and safety statistics [143].

For decommissioning considerations, see:

- UK Government, Decommissioning of Offshore Renewable Energy Installations Under the Energy Act 2004; Guidance Notes for Industry (England and Wales) [144].

3.5 Permitting

For a typical view of project development costs, see:

- BVG Associates' Guide to an Offshore Wind Farm report [145] or Wind farm costs page of website [146].

For examples of good practice for administering permitting, see:

- Planning Inspectorate, National Infrastructure Planning web page [148].
- Planning Inspectorate Legislation and advice web page [150].
- BOEM's National and Regional Guidelines for Renewable Energy Activities web page for the US [138].

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 [151].

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

- World Bank Environmental and Social Standards [116].
- IFC Performance Standards [93].

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" [156].

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

- The J. Levitz article, Cape Cod Wind Farm Tiptoes Ahead [157].
- A journal article focusing on regulatory uncertainty by Nathanael Hartland [158].

For more successful permitting journeys, see:

- Bureau of Ocean Energy Management, Vineyard Wind web page [160].
- Federal Infrastructure Permitting Dashboard for Vineyard Wind [161].

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 [162].

3.6 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 [133].
- New York State Energy Research and Development Authority (NYSERDA), 2020 Offshore Wind Solicitation (Closed) web page [182].
- UK Government Department for Business, Energy & Industrial Strategy (BEIS), Policy paper: Contracts for Difference [180].
- National Grid ESO, CfD Process [181].

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

- UK Government Final Investment Decision Enabling for Renewables web page [165].
- UK Government's Implementing Electricity Market Reform (EMR) paper [166].

For a discussion of fiscal support, see:

- KPMG, The Power of nature: taxation of wind power [164].

For a developer view of non-price factors, see

- SSE's Position Paper Non-price Criteria in Renewables Auctions [176].

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 [184].
- Nstar Electric, "Offshore wind generation unit PPA" [185].
- Inter-American Development Bank "Guide for Designing Contracts for Renewable Energy Procured by Auctions" [345].

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

- Ørsted, Ørsted and Amazon sign Europe's largest offshore wind corporate power purchase agreement [186].

For information on future options for power offtake, see:

- Huge offshore wind farm to power green hydrogen in Brazil [190].
- Ørsted to develop one of the world's largest renewable hydrogen plants to be linked to industrial demand in the Netherlands and Belgium [189].
- 'Multi-gigawatts': Asia pioneer eyes Brazil in offshore wind and green hydrogen pact [191].
- 'Green fuels will float many boats': hydrogen platform could help offshore wind crack Asia, says developer [192].

Further reading material for section 2.1 is also relevant.

3.7 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 [346].
- Offshore wind transmission study comparison of options, prepared for New Jersey Board of Public Utilities [206].

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

- The Green Giraffe's Offshore Wind Transmission, US presentation [210].

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 [347].

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 [348].

3.8 Health and safety

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

- The GWO's Basic Safety Training Standard [212].
- The Global Offshore Wind Health and Safety Organisation Good Practice Guidelines [213].
- Renewable UK's Offshore Wind and Marine Energy Health and Safety Guidelines [349].
- The World Bank Group's Environmental, Health, and Safety Guidelines for Wind Energy [350].
- The World Bank Group's Environmental, Health, and Safety (EHS) Guidelines cover both health and safety as well as environmental considerations [211].
- The World Bank's Environmental, health, and safety guidelines for offshore oil and gas development [351].
- World Bank's Environmental, Health, and Safety Guidelines for Ports, Harbors, and Terminals [352].

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

- The GWO's Training Agreement in New Jersey [215].

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

- Data from G+ Global Offshore Wind Health & Safety Organisation [143].

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 [219].

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 [218].

3.9 Standards and Certification

For information of international best practice relating to certification and standards, see:

- European Commission study on best practices in floating offshore wind energy technical regulations in the EU and Member States [353].

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 [342].

For guidance notes and reviews of certifications, see:

- Lloyds Register's Guidance Notes for Offshore Wind Farm Project Certification [354].

3.10 Community benefit

For examples of the impact of community benefits on renewables deployment, see:

- BVG Associates, Offshore renewable energy export potential for Ireland [226].

For examples of the advantages of community benefits, see:

- Energy Sector Management Assistance Program (ESMAP), The Strategic Value of Community Benefits in Offshore Wind Development [227].

For examples of coastal community regeneration se:

- Input from GWEC and Ørsted [228] [229].

4. DELIVERY

4.2 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 [234].
- The National Offshore Wind Research & Development Consortium (NOWRDC)'s website for an example of a funded program of cost reduction in offshore wind [235].

- New Jersey Economic Development Authority, Offshore wind tax credit: ERA update [236].

For examples of establishing national offshore wind innovation needs, see:

- UK Offshore Wind Industry Council Innovation focus on offshore wind [58].
- Sustainable Energy Authority of Ireland's Offshore Renewable Energy Technology Roadmap [59].

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 [235].
- The Carbon Trust's Offshore Wind Accelerator (OWA) web page for an example of joint industry projects in offshore wind [283].
- Danish Technical University, web page [284].
- Fraunhofer Institute for Wind Energy Systems, web page [285].
- National Renewable Energy Laboratory, Offshore Wind Research web page [286].
- Offshore Renewable Energy Catapult, web page [287].
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APPENDIX C: GLOSSARY

BEIS	Business, Energy and Industrial Strategy (Former 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)
DESNZ	Department for Energy Security and Net Zero (UK Government Department)
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
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
NID	Nature inclusive design
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
OSHA	Taiwan, China'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

Frameworks	Regulations, processes, and guidelines to give structure to different key aspects of the delivery of offshore wind.
Marine spatial planning	A process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas, informed by stakeholder engagement and sensitivity mapping.
Leasing	Providing exclusive rights to develop an offshore wind farm (and associated infrastructure) at a given location. Permits typically include a number of requirements for the developer to follow.

Permitting	Securing the environmental and all other permissions to install and operate an offshore wind project. Permitting typically includes a requirement for Environmental and Social Impact Assessment, and proportionate permitting conditions for management and monitoring of mitigation and offset measures.
Revenue support	Any public mechanism that supports through-life revenue to enable the decision to invest in an offshore wind project.
Export system	The equipment and assets required to connect offshore wind generating assets to the transmission network.
Grid connection	The approach taken to secure export capacity for an offshore wind farm, which subsequently connects to the wider electricity transmission network at the grid connection point.
Supply chain	The network of organizations that supply parts or services to the offshore wind sector.
Transmission network	The wider high voltage electricity network.

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ESMAP
Energy Sector Management Assistance Program